WHAT IS WRONG WITH STERN?

The Failings of the Stern Review of the Economics of Climate Change

Peter Lilley MP

Foreword by Professor Richard Tol

The Global Warming Policy Foundation
GWPF Report 9

GWPF REPORTS

Views expressed in the publications of the *Global Warming Policy Foundation* are those of the authors, not those of the GWPF, its Trustees, its Academic Advisory Council members or its Directors.

THE GLOBAL WARMING POLICY FOUNDATION

Director
Dr Benny Peiser

Assistant Director
Philipp Mueller

BOARD OF TRUSTEES

Lord Lawson (Chairman)
Lord Barnett
Lord Donoughue
Lord Fellowes
Rt Rev Peter Forster
Bishop of Chester
Sir Martin Jacomb
Henri Lepage
Baroness Nicholson
Lord Turnbull

ACADEMIC ADVISORY COUNCIL

Professor David Henderson (Chairman)
Adrian Berry (Viscount Camrose)
Sir Samuel Brittan
Sir Ian Byatt
Professor Robert Carter
Professor Vincent Courtillot
Professor Freeman Dyson
Christian Gerondeau
Dr Indur Goklany
Professor William Happer
Professor Terence Kealey
Professor Anthony Kelly
Professor Deepak Lal
Professor Richard Lindzen
Professor Ross McKitrick
Professor Robert Mendelsohn
Professor Sir Alan Peacock
Professor Ian Plimer
Professor B P Radhakrishna
Professor Paul Reiter
Dr Matt Ridley
Sir Alan Rudge
Professor Philip Stott
Professor Richard Tol
Dr David Whitehouse

What Is Wrong With Stern?

The Failings of the Stern Review of the Economics of Climate Change

Peter Lilley MP

Foreword by Professor Richard Tol

ISBN: 978-0-9566875-9-3
© Copyright 2012
The Global Warming Policy Foundation

Contents

Table of Contents	2
About the Author	2
Foreword	3
Introduction	5
Executive Summary	8
Chapter 1 - Background to Stern Review and its Reception	16
Chapter 2 - Key Criticisms of the Stern Review's Conclusions	18
Chapter 3 - Estimating the Impact of Global Warming	25
Chapter 4 - Costs of Restricting Emissions	37
Chapter 5 - Discount Rate	46
Annex to Chapter 5 : The Ramsey Equation	56
Chapter 6 - Treatment of Uncertainty and Risks	59
Annex to Chapter 6 - Is Stern "Right for the Wrong Reasons"?	66
Chapter 7 - Implications of Stern Review for Developing Countries	79
Chapter 8 - Policy Implications	84
Recommendations	92
Author's Acknowledgements	94

About the Author

The Rt Hon Peter Lilley MP

Peter Lilley graduated in Natural Sciences followed by Economics at Clare College, Cambridge. He worked as a development economist on aid projects for a number of years before becoming an investment analyst overseas, specialising in the energy industries. Elected to Parliament in 1983 he served as a minister between 1987 and 1997, initially as Economic Secretary, then Financial Secretary to the Treasury before joining the Cabinet as Secretary of State for Trade and Industry, then Social Security. He chaired the Global Poverty Policy Commission set up by David Cameron. He is currently Member of Parliament for Hitchin and Harpenden and Co-Chair of the All Party Parliamentary Group for Trade Out of Poverty.

Professor Richard Tol

Richard Tol is a Professor at the Department of Economics, University of Sussex and the Professor of the Economics of Climate Change, Institute for Environmental Studies and Department of Spatial Economics, Vrije Universiteit, Amsterdam. He received a Ph.D. in economics (1997) from the Vrije Universiteit. He published 194 articles in learned journals, 3 books, 5 major reports and 37 book chapters, He specialises in the economics of energy, environment, and climate. He is an author (contributing, lead, principal and convening) of Working Groups I, II and III of the IPCC.

Foreword

The publication of the Stern Review of the Economics of Climate Change was a PR exercise that was unprecedented in economics. Sir Nicholas, now Lord Stern, was portrayed as an expert even though he had never published before on the economics of energy, environment or climate. Nick Stern was presented as independent, although he was a senior Treasury official and had been a civil servant, first with international organisations, and latterly in the UK, for 12 years and was supported by a team of civil servants. The Stern Review was claimed to be the first ever economic analysis of and justification for climate policy, although similar studies had been published since the 1980s.

Five years after its publication, many people still seem to believe the myths that surround the Stern Review. Indeed, the Stern Review is regularly cited as a Higher Authority on all matters green and good, including on subjects not covered by the Stern Review.

In this report, Peter Lilley MP revisits the Stern Review and the economic case for climate policy. He shows that there are many errors, big and small, in the Stern Review. At first sight, that is what one would expect from a report on a complex subject written in a short time by a group of novices. However, Lilley also reveals that the errors are systematic and suggestive of an ideological bias.

Policy advice always mixes the normative and the positive. Policy analysis answers the question what if we do nothing or intervene in a particular way. But policy analysis is incomplete without addressing the so what and what to do questions. And there as well, the Stern Review adopted a position that is peculiar.

This is best illustrated with the discount rate. The discount rate has been debated by scholars since Socrates (and perhaps before that). Some of the brightest people in history have investigated the discount rate. The conclusion of all that effort is disagreement: Many positions are defensible, and any position is debatable. Honest policy analysts show results for a range of alternative discount rates. The Stern Review uses a single discount rate. It corresponds to an extreme position in the literature and it deviates from the official discount rate of HM Treasury. Nick Stern is, of course, free to use whatever discount rate he wants in his private life. Professor Sir Partha Dasgupta of Cambridge University has found that Stern should save 97.5% of his income, were Stern to follow the advice in the Stern Review. Taking such an extreme position in public policy is odd.

The problems of the Stern Review could have been avoided if the report had been reviewed, pre-publication, by experts in the field. That was not done because of a fear that Stern's peers would leak to the media; in fact, the media leaked the Stern Review to academics. It was reviewed post-publication,

and no expert in the economics of climate change has stepped forward to defend the assumptions and methods of the Stern Review. Most of the critique came from outside the UK, with most British economists keeping a studious silence, a wise move given the amount of research money since showered on Nick Stern. The more innovative parts of the Stern Review – the non-Newtonian calculus in Chapter 13, for instance – have yet to be submitted to learned journals. Nick Stern has withdrawn from all academic debate.

None of this detracts from the fact that there is an economic case for greenhouse gas emission reduction. We cannot be certain that greenhouse gas emissions do not cause climate change. We cannot be certain that climate change is harmless. In fact, most evidence points in the opposite direction. Although economic analyses have yet to reach any robust conclusion for climate policy in the medium- to long-term, the recommendations for the short-term are widely shared among economists: We should start with emission reduction now, while simultaneously developing the institutions and technologies in case we would need deeper emission cuts later.

Overly ambitious emission reduction in the short run, as embraced by the European Union and the United Kingdom, is needlessly expensive. It is also divisive, particularly when based on flawed analysis like that in the Stern Review. It will take a century to solve the climate problem. Most economic studies conclude that it is best to start with modest emission reduction, and accelerate the stringency of climate policy over time. For that, public policy will need to pull into the same direction over 20 or more electoral cycles. If the case for climate policy is exaggerated, the backlash will come, sooner or later. The Stern Review was a tactical masterstroke, but it will likely prove to be a strategic blunder. Its academic value is zero.

Professor Dr Richard S.J. Tol MEA

University of Sussex

Vrije Universiteit Amsterdam

Introduction

Government plans to combat man-made global warming are perhaps the most costly programme since the introduction of the Welfare State – over £17,000 per household.[1] Yet, despite widespread academic criticism they have not received the scrutiny they merit from Parliament, media or public.

Ministers still rely almost entirely on the Stern Review of the Economics of Climate Change to justify their policies. Yet Stern's estimates of the costs and benefits of preventing global warming differ markedly from the consensus among environmental economists and even from the economic assessment of the UN Inter-governmental Panel on Climate Change (IPCC) on whose scientific projections they were based. Whereas Stern said the benefits of reducing emissions would be 5 to 20 times the cost, the IPCC shortly afterwards concluded:

> "analyses of the cost and benefits of mitigation indicate that these are broadly comparable in magnitude"

so it could not establish

> "an emissions pathway or stabilization level where benefits exceed costs."[2]

Ministers constantly urge the public to accept the IPCC's assessment of the science of global warming because it has the support of most scientists, yet they ignore the IPCC's economic conclusions which are supported by most environmental economists.

The Review's message was crisp and dogmatic: immediate action is required to avoid catastrophe; carbon dioxide emissions must be almost eliminated by 2050 to prevent greenhouse gas concentrations exceeding 550 ppm; any lower target is unobtainable; any higher target disastrous; we must ration carbon emissions by issuing tradable quotas, backed up by a battery of regulations, subsidies and taxes, the cost of which (it claims) will be astonishingly modest.

Given the public mood when it was published the Stern Review was adopted as Gospel truth; by politicians – because it endorsed an apparently vote winning message; by the media – because the global warming story sold newspapers; and by environmentalists - because it validated their agenda.

Because there was no debate few ministers, MPs or journalists realise that there are alternative strategies involving different time scales, targets, economic instruments and trade-offs between prevention and adaptation.

---

1 The revised Impact Assessment for the Climate Change Act 2008 estimated the present value of the cost of this Act at up to £430 billion. This excludes transitional costs which it says could be 1.3-2% of GDP up to 2020, and the cost of driving industry abroad, which it says could be significant. There are some 25 million households in the UK.

2 IPCC, Climate Change 2007: Mitigation of Climate Change (Working Group III Contribution to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change). Cambridge, UK: Cambridge University Press, 2007, p. 18.

Nor are they aware that, on Stern's calculations, the sacrifices this generation is asked to make to prevent global warming will accrue centuries ahead when people will be many times richer than us and far better equipped to adapt to, prevent or even reverse global warming. Moreover, the worst threat - of melting icecaps raising sea levels dramatically – would, according to the IPCC, take millennia to arrive - even if temperatures rise substantially.

Why return to the economics of climate change now? Recently the public mood has changed. Austerity makes people hard-headed. The costs of cutting emissions have begun to hit households and companies. Global warming seems to have paused in recent years. The 'Climategate' emails and IPCC scandals dented public confidence in scientists' predictions that warming will resume. Political parties committed to costly climate policies in Canada and Australia have faced setbacks; Obama's Cap and Trade Bill sank without trace, the Copenhagen conference broke up without agreement and subsequent conferences achieved even less. Meanwhile there is growing awareness that the UK's contribution to world emissions is tiny - barely 2% of the total and less than the increase in China's emissions in a single year. And China has no intention of signing up to a binding commitment to cut its emissions.

Economic difficulties are no reason to question the science of global warming and this study does not do so. Virtually all climate scientists – from sceptics to alarmists – accept that increasing concentrations of greenhouse gases will raise temperatures, other things being equal. The only scientific disputes are about how much, how certain and whether other things are equal. However, economic pressures do justify questioning whether the economics of climate change policy is sound.

In order to focus exclusively on the economics, this paper - like the Stern Review - takes the IPCC's assessment of the science as given. This does not mean that Stern's treatment of the science is acceptable. That has been powerfully challenged in a critique[3] whose authors foresaw that:

> "the Stern Review appears as a misdirected exercise. By taking as given hypotheses that remain uncertain, assertions that are debatable or mistaken, and processes of inquiry that are at fault, the Review has put itself on a path that can lead to no useful conclusion".[4]

Stern's selective emphasis on alarmist interpretations and downplaying of uncertainties exacerbates a tendency of the IPCC which the Council of National Science Academies has criticised:

> "for emphasising the negative impacts of climate change … the authors reported high confidence in some

3 *The Stern Review: A Dual Critique: The Science* Robert M. Carter, C. R. de Freitas, Indur M. Goklany, David Holland & Richard S. Lindzen: *Economic Aspects* Ian Byatt, Ian Castles, Indur M. Goklany, David Henderson, Nigel Lawson, Ross McKitrick, Julian Morris, Alan Peacock, Colin Robinson & Robert Skidelsky. World Economics Oct-Dec 2006.

4 Byatt et al. 2006. *The Stern Review "Oxonia" Papers: A Critique* (World Economics, Vol. 7, No 2).

statements for which there is little evidence".[5]

This study simply challenges Stern's economic methods and conclusions – and shows his Review was an exercise not in evidence-based policy making but in policy-based evidence making.

5 *Climate change assessments: Review of the processes and procedures of the IPCC*. InterAcademy Council October 2010 pxv.

Executive Summary

Time to review the Stern Review

The government relies on the Stern Review to justify its policies to combat global warming – possibly the most costly programme since the welfare state. But the Stern Review was not fit for purpose.

The Review's conclusions were way outside the consensus of economic studies it supposedly reviewed and have been roundly criticised by many leading economists. Indeed, Stern's conclusions, that the costs of a crash programme to reduce emissions are far outweighed by the benefits, contradict even the Intergovernmental Panel on Climate Change (IPCC) which said: "costs and benefits are broadly comparable in magnitude" so it could not establish "an emissions pathway or stabilisation level where benefits exceed costs".

These criticisms were ignored when Stern's report was published since political parties, media and environmentalists welcomed its conclusions as incontrovertible truth. However, the mood has changed since the recession, as the costs of climate subsidies hit homes and businesses and the Climategate emails provoke scepticism. It is time to look anew at the economics of tackling climate change (while taking as given the IPCC's assessment of the science – in order to focus exclusively on the economics of climate change policy).

Key conclusions misleading and not comparable

Stern's headline conclusions were that:

> "If we don't act, the overall costs and risks of climate change will be equivalent to losing at least 5% of global GDP each year now and forever."[6]

whereas

> "The costs of action – reducing greenhouse gas emissions to avoid the worst impacts of climate change – can be limited to around 1% of GDP each year."[7]

They succeeded in giving the clear impression that we face huge losses now which could be averted at a fifth of their cost. But this is achieved by verbal virtuosity combined with statistical sleight of hand. In fact, even on Stern's figures, the cumulative costs of reducing greenhouse gases will exceed the

6 Stern Review page xv (NB all footnotes about the Stern Review refer to the printed version)

7 Ibid

cumulative benefits until beyond 2100. Stern's misleading headlines rely on comparing apples and pears as well as conflating predictions centuries hence with the present.

- **Comparing apples and pears** – or the whole of an apple with part of a pear. Stern compares the cost of limiting the amount of global warming with the benefit of eliminating it entirely.[8] The benefit of preventing it entirely would, on his figures, be at least 5% of GDP – but to do so would require not just stopping all further carbon emissions but removing all those accumulated since the industrial revolution. The action he proposes to reduce the worst impacts of global warming by stabilising the atmospheric concentration of greenhouse gases at 550 ppm would, using Stern's methodology, save some 3.1% of GDP – not 5%. The Review headlines put the cost of meeting his emissions target at 1% of GDP, though Stern has since doubled that and, in the body of his report, the cost was put at up to 4% of GDP.[9]

  The larger the damage which will still occur if emissions are stabilised at Stern's target, the more misleading the comparison Stern makes between the cost of reducing damage and the benefits of eliminating emissions entirely. The smaller the residual climate change damage if emissions are stabilised at 550 parts per million (ppm), the less compelling the case for stabilising at that level.

- **Describing future centuries as "now".** Stern suggests losses from global warming will be at least 5% of GDP "each year now and forever".[10] This is simply untrue. The cost of his crash programme to reduce emissions does indeed start now and in the decades to come. But the impact of global warming which he wants to mitigate will be largely in the very distant future. Even on Stern's questionable calculations, *it will be the next century before the cumulative benefits of (entirely) preventing global warming would exceed Stern's low estimate of the costs of (partially) limiting it.*[11] Stern justifies his claim by saying losses from global warming centuries ahead are statistically "equivalent to" losses "now and forever". He calculates the "now and forever" figure by taking high losses reached centuries ahead and projected to infinity, then discounting and averaging them with the negligible losses for many decades to come.

- **Hidden economic assumptions.** Since Stern projects the impact of global warming to infinity, the rate at which he discounts them to the present is crucial. Stern rejects discount rates normally used to compare future costs and benefits – including the rates specified by the Treasury Economic Service which he headed. Instead he adopts an ultra-low rate without explicitly disclosing it in his 700-page report. His low discount rate

8 The comparison first appears in the opening paragraphs of the Summary of Conclusions, page xv Stern Review.

9 Stern Review Chapter 9 using a bottom-up assessment of technologies puts the cost "in the range -1.0 to + 3.5% of GDP" p 239; Chapter 10, using a macroeconomic model of costs, says costs are "most likely to be around 1% of GDP, +/-3%" p 268.

10 Ibid the phrase first appears on page xv

11 Ibid see Figure 6.5c page 178

and infinite time horizon mean that over half the projected losses this generation will be paying to avoid will not occur until several centuries hence.

Stern justifies his ultra-low discount rate as being rational and ethical – arguing that discounting for time is irrational and we should value the well-being of future generations as much as our own. Since discounting to infinity at a zero rate would put an infinite value on even the smallest reduction of emissions, he discounts time at 0.1% per annum (pa) to allow for the risk of extinction (for reasons other than climate change). He also recognises that benefits accruing to people with higher incomes are less valuable. So he discounts benefits accruing to future generations by the growth in their incomes relative to today – which he puts at 1.3% pa: hence his total discount rate of 1.4% pa.

- **Inconsistent discounting of costs and benefits.** Although Stern discounts benefits of curbing emissions at an ultra-low rate, he does not discount the true cost of doing so – the returns foregone on alternative investments – at the same low rate. As a result, his estimate of the cost of avoiding climate change is understated relative to his estimate of the benefits by a factor of between 2 1/2 and 5 times.

  Arguably he is entitled to use a low discount rate, but only if he accepts that, logically, he should advocate investing in a Norwegian-style 'fund for the future', not just in mitigating climate change but in any projects with returns above his discount rate until the market rate and his discount rate converge.

- **Peculiar ethical assumptions.** Normal ethics of external costs would require users of fossil fuels to pay a charge sufficient if invested at market rates to compensate future victims of sufficient global warming (which would prompt switching away from fossil fuels if that is less costly than paying the levy). The charge would therefore equal future damages *discounted at the market rate*. So Stern segues away from the polluter pays principle to base his ethics on a utilitarian welfare maximising approach, which envisages a single "decision-maker acting on behalf of the community and whose role is to improve, or maximise overall social welfare."[12] The ethical values attributed to the perfectly rational decision maker imply that this relatively poor generation should be required to sacrifice up to 5% of their income to ensure that people in 2200, whose average incomes, even on Stern's most pessimistic scenario, will be over 7 times higher than today's, do not suffer a 5% loss of income. He castigates those who do not share this view as "not caring for future generations". Yet arguably it is more ethical to care about today's poor than tomorrow's rich. Moreover, those who put a supreme value on the existence of the human race would not need to use an ultra-low discount rate to justify action if they believed human survival to be at risk.

12 Stern Review page 31

- **Not discounting for uncertainty.** It is common to use a higher rate of discount for greater uncertainty since that attaches less weight to less certain, more distant events. But Stern says the greater the uncertainty about the impact of carbon emissions, the lower the rate of discount should be. He argues that the less certain we are, the wider the dispersion of potential outcomes and incomes; lower incomes reduce the element of his discount rate which reflects the difference between future and current incomes. Conversely outcomes at the top of the potential range of dispersion will be discounted more heavily; so the average will be weighted towards less discounted 'bad' outcomes. He tacitly assumes we can be certain about the structure of the future, apart from the dimension of the impact of climate change. In fact, the future is likely to be different in utterly unforeseeable ways. It requires supreme hubris to assume that the only uncertainty about how our actions now will affect the world centuries hence, is the precise magnitude of the impact.

- **Clutching at catastrophes.** Even Stern's base case assumes that higher temperatures might precipitate three catastrophic consequences: (i)the release of methane from the tundra or oceans – but this did not happen on a significant scale during previous periods of rapid warming; (ii) the reversal of the gulf stream - which is not predicted by the IPCC and would offset global warming, scarcely a catastrophe; and (iii) the melting of the icecaps - which the IPCC says will take millennia, giving plenty of time to change course or counteract emissions.

- **Denying scientific certainty.** Stern's team fall back on the suggestion by Martin Weitzman that Stern may be right for the wrong reasons. Weitzman argued that if there is a finite possibility, however small, of an infinitely bad outcome (human extinction) then virtually any cost is worth incurring to prevent it. To forecast infinitely bad outcomes, ironically Stern has to jettison his belief that "the science is certain" and postulate a response of climate to greenhouse gases beyond anything known to physics. Climate sensitivity is not a random variable, so if it is high its impact must currently be concealed by natural variations and should soon become obvious as those fluctuations reverse, giving plenty of time to respond. Also, by Weitzman's logic we cannot neglect the risk that measures to prevent emissions have infinitely bad outcomes: e.g. reliance on nuclear energy resulting in nuclear proliferation and war; without green house gas emissions we may enter an ice age; etc. And other tiny but terminal risks such as asteroids hitting the earth would compete with global warming for huge outlays.

- **Cherry picking unreliable studies.** Stern draws heavily on non-peer reviewed and alarmist literature to paint an exaggerated picture of the key risks of global warming:

  a) **Hurricanes and storms.** A World Bank study shows that Stern's forecasts of damage to infrastructure from more powerful storms are up to 100 times too large - being based on extrapolating a non-peer

reviewed paper which attributed much of the growth of insurance claims (which is mainly the result of more properties being built in storm-prone areas) to greater prevalence of more powerful storms. There is scant evidence of this. The IPCC is uncertain, citing models indicating that the number of storms may decline but intensity may increase.

b) **Food and famine.** He neglects scope for adaptation (citing a study showing a 4 degree Celsius rise could cut yields of one crop variety by 70% but assumes farmers will not switch to another variety whose yields would increase – a fact he withholds). He says a 4°C rise would cut world cereal production by 10%. But he accepts that meeting the bio-fuels target will absorb 10% of the world's arable land. In any case this is insignificant given the massive scope to boost output by using existing agricultural techniques more widely.

c) **Water supplies.** Higher temperatures mean more precipitation overall. But Stern highlights the number of people forecast to suffer increased water stress, although twice as many will enjoy reduced water stress.

d) **Rising sea levels.** This is the most iconic fear aroused by global warming but the IPCC says it will take millennia for higher temperatures to melt the ice-caps. Meanwhile the oceans are set to rise at a rate similar to the average of the last 18,000 years. A World Bank study suggests that even Bangladesh can prevent projected storm surges at a cost of barely 1% of its GDP.

e) **Disease.** Stern relies on a study which arbitrarily assumes 2% of all deaths from diarrhoeal diseases, malaria and malnutrition are the result of climate change and that this will double for each 1°C rise in temperature. But these are diseases of poverty and invariably disappear as countries experience economic growth.

- **Neglecting adaptation, reduced vulnerability and technological advances.** Apart from cherry picking alarming studies, Stern systematically downplays or ignores possible trade-offs between adaptation to, and prevention of, climate change; he assumes poor countries remain vulnerable to climate change whereas economic growth makes countries much more resilient; and he neglects likely technological changes – like GM crops, vaccines for malaria and other diseases, sturdier buildings for hurricane zones, etc.

- **Reliance on models to predict damage.** Despite using alarmist studies to depict a frightening future, his actual estimates of climate damage depend on an essentially arbitrary algebraic formula embedded in the Integrated Assessment Model he uses. This reduces all the consequences of climate change to a single variable and assumes they occur as soon as a given temperature is reached – effectively bringing forward the possible impact of melting ice-caps by millennia.

- **Underestimating cost of reducing emissions.** Although the IPCC concludes that it is impossible to say whether the cost of preventing global warming would be more or less than the benefits of doing so, Stern claims the costs will be only a fifth to a twentieth of the benefits.

  Embarrassingly, given he was head of the government's economic service, his estimate is well below the UK government's own estimate of the cost of the Climate Change Act and also below the lowest of 21 studies collated by Stanford University.

  He selects the most optimistic estimates which assume costs of alternative energy sources will fall rapidly. Yet if they are set to do so it is foolish to adopt new technologies prematurely while the cost is still so high.

  He puts immense faith in Carbon Capture and Storage – as yet commercially unproven - since he assumes 75% of electricity will still be generated using hydrocarbons.

  If Stern applied his ultra-low discount rate to the true cost of investing in decarbonising the economy (the returns foregone on alternative investments), it would increase his cost estimate up to five-fold.

- **Sacrificing today's poor for tomorrow's rich.** Poor countries are more vulnerable to global warming – because they are poor. The cure for poverty is growth, which requires energy.

  Requiring poor countries to replace fossil fuels by renewables costing upwards of twice as much will hinder their growth, leaving them vulnerable to global warming.

  Stern admits the bio-fuel target will require 10% of the world's arable land, driving up food prices by more than the yield loss he expects if temperatures rise 4°C.

  Developing countries will account for the bulk of growth in emissions on a 'business as usual' scenario as the poorest two-thirds of the world's population catch up with the most developed nations. So Stern's crash programme to limit emissions would involve major restraint by them even if developed countries decarbonise almost totally.

  Emissions trading would allow rich countries to cut their emissions by less in return for paying poor countries to cut by more, using more costly methods than they would otherwise have done. Subsidies for low carbon development will divert aid from other uses; impose an additional layer of bureaucracy on developing countries; create huge opportunities for abuse; and encourage countries to threaten high emission schemes unless paid to abandon them.

  In practice, developing countries have no intention of slowing down their growth while millions of their citizens are living in poverty.

Stern presents China's plans to get back to their previous path of rising energy efficiency as "cuts" whereas their growth plans imply massive increases in their total emissions.

Policy implications conflict with consensus and governments' own cost benefit analysis

Stern sets a target of stabilising the atmospheric concentration of carbon dioxide at 500 to 550 parts per million (ppm). This would ultimately require reducing emissions by more than 80% from current levels. Developed countries would have to do so by 2050.

Stern does not evaluate alternatives nor demonstrate that this is the optimum target (nor mention that it was the target already adopted by the UK government).

To achieve this, the price of carbon must be raised by taxing or pricing emission permits to reflect its social cost, which he puts at $310/ton of carbon rising to $950/ton by 2100.

The consensus of conventional economists was that the optimum path was to intensify the effort more gradually. For example, Nordhaus's optimum path involves an initial Social Cost of carbon of $27/ton of carbon to cut emissions by a quarter by 2050 against Stern's three-quarters.

Gradually intensifying the effort avoids prematurely abandoning existing capacity or adopting new technologies while still too expensive and allows time to reach firmer estimates of climate sensitivity.

The British government ignored its own impact assessments, which showed potential costs of its Climate Act were twice the maximum benefits and costs of its Feed-In Tariffs were 20 times their benefits.

The subsequent revision increased benefits of the Act ten-fold by assuming that the rest of the world follows the UK example, which undermines the case for unilateral action.

Developing countries like China and India have no intention of following suit. The increase in China's emissions every year exceeds the UK's emissions, which are just 2% of the world total. And despite Stern's optimistic belief that public opinion would force countries to adopt and observe stringent international targets, both Canada and Japan have resiled from Kyoto commitments.

Key Recommendations

The government should cease to rely on the flawed Stern Review to justify policy and should commission a new, independent Review.

The government should prescribe the same discount rate for assessing costs and benefits of climate policies as it uses for all long-term public projects or explain fully why it is not so doing – and show the sensitivity to alternative plausible discount rates and the Internal Rate of Return of alternative pathways for tackling global warming.

The Review should assess the impact of global warming specifically on the UK and include in figures for UK emissions estimates of carbon emitted to produce goods imported into the UK.

The Review should assess the cost and benefits for scenarios with varying degrees of international cooperation. Meanwhile, Parliament should remove the legal requirement on the UK to act unilaterally.

In the absence of a new Review, government strategy should at most involve:

- gradually ramping up incentives to reduce carbon emissions
- cost effective measures to increase energy efficiency
- greater focus on incentivising Research and Development
- acceptance that developing countries need to develop the cheapest energy sources available to them
- more emphasis on adaptation to climate change as it occurs
- focussing development aid on helping vulnerable countries adapt to climate change, whatever its cause.

Chapter 1 - Background to Stern Review and its Reception

"The effort expended in prising open the oyster led some to overvalue the pearl within". Professor Harry Johnson.

In July 2005, Gordon Brown, then Chancellor of the Exchequer, announced that he had asked Sir Nicholas Stern – an academic economist turned Treasury official, by then the Permanent Secretary responsible for the Government Economic Service - to undertake a major review of the economics of climate change. Sir Nicholas (now Lord Stern) led a team of 23 Treasury economists and officials, supported by many consultants, who worked on the review for 16 months at a cost of £1.27 million.[13] Their 700-page report, entitled the Stern Review of the Economics of Climate Change, was press released with considerable fanfare at the end of October 2006.

Several features are unusual and affected its initial reception:

• It was first published online and physical copies were only made available two months later. As a result, the initial response to such a massive work was heavily dependent on briefing material provided by the Review team.

• The media amplified uncritically its most stark and dramatic conclusions.

"Climate change fight 'can't wait'" BBC News

"£3.68 trillion: the price of failing to act" The Guardian

"The day that changed the climate" The Independent

"Blair: World needs to act on climate change now" Daily Mail

"British Government Report Calls for Broad Effort on Climate Issues" New York Times

"Report's stark warning on climate" BBC News Channel

• Although treated in public as an independent study, it was essentially a government report.

• It was not subjected to independent peer review.

• Rather than analysing a range of possible targets for stabilising emissions, it focussed on, and recommended, just one - which happened to be the

13 Hansard 13 Jan 2011 Reply by Justine Greening. "This figure does not include the costs of any analysis and research carried out by other government departments to support the review, nor any follow up work …"

target to which the UK government was already committed (though this was not mentioned in the Review).

The relationship between the Stern Report and the IPCC appears to have been somewhat incestuous. The Stern Review was published in October 2006, whereas the IPCC Fourth Assessment Report (known as AR4) did not appear until 2007. So Stern used the IPCC Third Assessment Report (TAR), published in 2001, as the base for its science, supplemented by studies published since then, many of which were subsequently assessed in AR4. The Stern Review was not peer-reviewed so was theoretically not itself eligible for inclusion in the AR4. In any case, the final date by which expert reviewers were required to submit their comments for studies to be included in the AR4 was some months before Stern was published. Remarkably, the AR4 nonetheless refers to the Stern Review no fewer than 26 times in 12 different chapters – only two of which relate to the economics of climate change. Indeed the AR4 uses Stern as the sole source of its claim that three-quarters of a billion people in China and India depend on glaciers for their water supply.[14] This raises concerns about the IPCC process. This study nonetheless takes the IPCC assessment of the scientific literature as given, as did Stern.

The Review was opaque as to its key assumptions – notably the discount rate used - and contained no sensitivity analysis. So it was difficult for commentators to deduce how the Review managed to reach conclusions so widely different from the bulk of the work it was reviewing. The team did subsequently make good this omission by publishing a sensitivity analysis online.

Although the Government cites the Review in defence of its policies, it ignores conclusions which do not help its case. For example, the former Energy and Climate Change Secretary, Chris Huhne, asserts that renewable energy will end up costing less than fossil fuels as they become increasingly scarce. Yet Stern poses the question:

> "Will increasing scarcity drive up the relative prices of fossil fuels to choke off demand fast enough?"

and concludes

> "There is enough fossil fuel in the ground to meet world demand at reasonable cost until at least 2050".[15]

In February 2007, the Yale Center for the Study of Globalization held a seminar bringing Stern and many of the world's leading environmental economists together to discuss his Review. It received a comprehensive battering, albeit couched in polite academic language. A number of papers criticizing various aspects of the Stern Review were published in the peer-reviewed literature. But this made no impact outside academic circles.

14 Donna Lafromboise IPCC Expose: the delinquent teenager who was mistaken for the world's top climate expert. The Stern Review seems to rely on an article by Barnett et al in Nature 2005.

15 Stern Review p. 212.

Chapter 2 - Key Criticisms of the Stern Review's Conclusions

"The science is intricate. But it is a doddle compared to the economics and politics of climate change. Nick Stern has averred that it needs 'all the economics you ever learnt, and some more'." Lord Rees[16]

The Stern Review could have been an admirable basis for a debate on the economics of global warming. It assembles a wealth of information, contains plenty of penetrating insights and makes provocative and challenging judgements. Unfortunately, rather than being used to stimulate public debate, it has been used to silence dissent from the official orthodoxy - at least in public, if not in academe. It is still routinely invoked by Ministers and in government documents as providing an incontestable basis for their latest measures.

The intelligent lay reader and even the professional economist could not readily work out how the Review had reached its conclusions – though the conclusions themselves seemed clear, dramatic and - to the layperson - plausible.

As a result the Review's conclusions became established as proven before their rationale was understood or subjected to criticism.

The three principal conclusions were dramatic:

- "If we don't act, the overall costs and risks of climate change will be equivalent to losing at least 5% of global GDP each year now and forever. If a wider range of risks and impacts is taken into account, the estimates of damage could rise to 20% of GDP or more".

- "In contrast, the costs of action – reducing greenhouse gas emissions to avoid the worst impacts of climate change – can be limited to around 1% of GDP each year."

- "Our actions now and over the coming decades could create risks of major disruption to economic and social activity, on a scale similar to those associated with the great wars and the economic depression of the first half of the 20th century."

Overall, these give the impression that for a modest cost we can prevent damages which are imminent, would cost us five to twenty times as much and would involve large scale loss of lives and livelihoods. However, these conclusions are highly misleading and misrepresent the body of the Review

16 Royal Society Lecture 5th December 2011

itself. They involve comparing apples and pears, conflating predictions centuries ahead with the present, inconsistent discounting of costs and benefits, and cherry picking alarmist projections.

Comparing apples and pears

Or rather, comparing a part of an apple with the whole of a pear. Stern compares the cost of reducing emissions not with the reduction in damage as a result of lower emissions but with the total damage caused by all greenhouse gas emissions – both those he plans to prevent and those which will still be permitted plus all those that have accumulated since the industrial revolution! In Stern's base case and using his metric, the net benefit from meeting his emission target would actually be equivalent to 3.1% of GDP "now and forever", not 5%.[17]

Stern only makes an obscure reference to this issue half-way through his report. He suggests that:

> "Allowing for uncertainty, if the world stabilises at 550 ppm CO2, climate change impacts could have an effect equivalent to reducing consumption today and forever by about 1.1%."[18]

This is somewhat less than estimated by Tol, though on a different basis. The Review is understandably coy about this issue. The larger the difference between the net benefit of stabilising emissions and the total damage if emissions are not curbed, the more egregious its error in comparing the cost of reducing emissions with the total damage caused by all emissions. On the other hand, the smaller the residual damage caused if we stabilise at 550 ppm, the less compelling the case for setting such a low level. Although the Review does not carry out a systematic cost/benefit analysis of different emission stabilisation levels, it does let slip that setting the emission level at 650 ppm would only increase damages by the equivalent of some 0.6% of GDP "now and forever".

Describing the distant future as "now"

The statement that the costs of climate change "will be equivalent to losing at least 5% of global GDP *each year now and forever*" (emphasis added) gives the impression that we are about to experience a loss of "at least 5%[19] of GDP now" due to global warming. The key words "equivalent to" are invariably overlooked.[20] They refer to the Review's novel and misleading

17 The Stern Review: a deconstruction: Tol and Yohe, Energy Policy 37 2009.

18 Stern Review page 333.

19 The words "at least" are also contentious. The body of the report shows that a 5% loss of GDP averaged over time is the mean for his Base Line Case, not a minimum. The 95% probability range for this case is between an averaged loss of just 0.6% and 12.3% of GDP. Stern Review Table 6.1 page 186.

20 Even the government does so. For example, the DECC Impact Assessment of the Climate Change Act quotes Stern as

practice of projecting by how much unrestricted climate change would reduce GDP each year from now (when the reduction is negligible) to infinity (when it will be large), discounting it back to the present, and then calculating what constant percentage reduction in GDP, discounted back to the present at Stern's very low rate of discount, has the same present value.[21] To say this averaged value – which reflects high impacts centuries hence – reflects the impact of climate change on GDP "now" is simply untrue. In fact, far from experiencing a 5% loss of GDP now, the impact of warming could be beneficial now and for several decades since moderately higher temperatures boost crop yields, as do increased concentrations of CO2.

Understating costs

The second conclusion - that costs "can be limited to around 1% of GDP each year" is more optimistic even than the body of the Review, where it says "the expected annual cost … is likely to be around 1% of GDP by 2050 with a range of +/-3%".[22] It is below any of the 21 studies monitored by Stanford University. Moreover, Stern has subsequently doubled his cost estimate, saying that we need to aim for the bottom end of his target range of emission cuts "costing about 2 per cent of global GDP each year".[23] Costs will start to be incurred "now" and for the foreseeable future. Even Stern's low estimate exceeds the likely cost of climate change this century since the gloomiest scenario which Stern depicts, in which global warming reduces GDP "now and forever" by 14.4%, actually involves losses averaging less than 1% of world GDP over this century: they reach just 0.4% by 2060 and 2.9% in 2100, rising to 13.8% in 2200.[24] So he is now proposing that throughout this century the world should spend over twice his pessimistic estimate of the cumulative damage caused by global warming over the whole of this century (only part of which would be prevented).

Inconsistent discounting of costs and benefits

Although Stern discounts benefits of curbing emissions at an ultra-low rate, he does not discount the true cost of preventing this – which is the rate of return foregone on alternative investments – at the same low rate. As a result, his estimate of the cost of avoiding climate change is understated by a factor of between 2 1/2 and 5 times.[25]

concluding that the cost of climate change if we do nothing "is estimated at 5% to 20% of global GDP now and forever" omitting the words "equivalent to".

21 Stern Review pages 183-5 (Box 6.3)

22 Stern Review Chapter 10 page 267.

23 Stern N. Time for a Green Revolution New Scientist 21 Jan 2009.

24 Stern Review Figure 6.5c page 178.

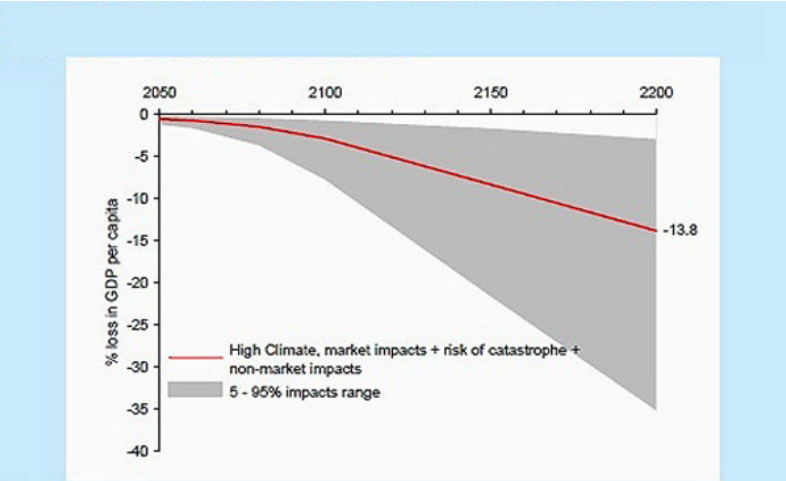
25 Robert Mendelsohn makes a similar point in "A Critique of the Stern Report", *Regulation* Winter 2006-2007

Alarmist cherry picking

Stern's third conclusion gives an overly dramatic picture of the likely damages caused by global warming. To compare it with the impact of two world wars and the Great Depression implies global warming will cause massive loss of life and livelihoods. This is not supported by the text of the report, still less by the IPCC. In fact, the Stern Review projects a world in which, even if we do nothing to prevent global warming, average incomes will rise by, on the gloomiest scenario, seven times and otherwise up to twelve times their current level by 2200. The effect of mitigating global warming would be to ensure incomes are at the high end of that range – at the cost of today's far poorer generation. Moreover, the main impact of global warming is likely to be on the physical environment – damage to infrastructure from more frequent and powerful storms and floods and a gradually rising sea-level - not loss of human lives.

It is useful to show Stern Review's most extreme outcome would mean for people over the next two centuries using his figures. He shows losses of income per capita for a number of scenarios, of which the most damaging is shown in Figure 1, reproduced below. This figure takes into account all of Stern's most alarming assumptions. It assumes that no effort is made to reduce 'business as normal' emissions of greenhouse gases. It also includes the weighted risk of possible catastrophes (melting ice-caps, reversal of the Gulf Stream, and release of methane clathrates). It adds in the impact of Stern's 'High Climate scenario', which assumes that emission of methane from the soil and frozen tundra amplify global warming. Finally, Stern deducts from GDP the impact of warming on non-market factors such as health, environment and species loss, even though these are not included in GDP. The central estimate for this scenario is a loss of welfare equivalent to 13.8% of GDP per capita by 2200. But the Review also allows a wide range of outcomes by running the model with different values of the key variables. 95% of these runs give losses of less than 7.5% of GDP in 2100 and 35% of GDP in 2200.

Figure 1: The impact on GDP of the Stern Review's most extreme scenario



Source: Stern Review

Table 1 below shows average GDP/welfare per capita for developing countries and industrialised countries assuming losses at these extreme levels occur. Despite these losses, people in developing countries are still expected to have average levels of well-being more than six times their current incomes by 2100 and 20 times by 2200, when their incomes will be two-thirds higher than incomes of people in the industrialised world today.[26]

26 GDP per capita in 2100 taken from Scenario A2 in IPCC SRES and projected from 2100 to 2200 at 1.5%pa for developing countries and 0.9% for industrialised countries, giving the overall growth of 1.3%pa indicated by the Stern Review.

Table 1: Stern's Estimate of the Worst Cost of Global Warming

Scenario A2 adjusting for Stern Review's highest 95th percentile estimate of costs of climate change assuming High Climate, market impacts, risk of catastrophes, non-market impacts (health, environmental, species loss etc).

			Scenario A2	
	1990	2006	2100	2200
Developing Countries				
GDP per capita, no global warming	$900	$1,500	$11,000	$49,000
Max cost of climate change	0	0	$800	$17,200
Net welfare per capita, with global warming	**$900**	**$1,500**	**$10,200**	**$31,800**
Industrialised countries				
GDP per capita, no global warming	$13,700	$19,300	$46,200	$117,000
Max cost of climate change	0	0	$3,500	$41,000
Net welfare per capita, with global warming	**$13,700**	**$19,300**	**$42,700**	**$76,000**
World total				
GPD per capita, no global warming	$3,800	$5,100	$16,100	$58,600
Max cost of climate change	0	0	$1,200	$20,500
Net welfare per capita, with global warming	**$3,800**	**$5,100**	**$14,900**	**$38,100**

Sources: IPCC Special Report Emission Scenario, Stern Review

The figures in Table 1 are before any discounting and without the statistical adjustments Stern uses to give a 'now and forever' figure.

Even professional economists took some time to unravel the Review's key assumptions that gave results far removed from those of most people working in the field on whose studies his Review was supposedly based. These only became apparent once the authors of the Review belatedly published a sensitivity analysis.

Stern's estimates of the harm unchecked global warming will do to humankind are ten to twenty times[27] the average of those in the literature

27 Stern Review of the Economics of Climate Change Reviewed by Gary W. Yohe and Richard S. J. Tol Environment vol 49 no2.

he reviewed.[28] This is particularly remarkable given that he does not claim to have done any original research himself.[29]

So how did he arrive at such a different result? Critics have identified several key factors which account for the Stern Review's high estimates of the impact of global warming:

- Pessimistic choice of economic and population scenarios coupled with cherry picking of worst case projections of damages from climate change.

- Understating the scope for adaptation, neglecting the decline in vulnerability to harm as economies develop and ignoring likely technical developments which will eliminate some problems.

- Reliance on models which project damages on the basis of an algebraic formula – damages which have no clear physical counterpart. The formula also assumes that high temperatures have instant impact whereas the worst impacts like melting the icecaps would need higher temperatures to be sustained for centuries if not millennia.

- The Review's estimates of the cost of reducing emissions to acceptable levels are as optimistic as his estimates of the likely scale and damage of global warming are pessimistic.

These are the focus of the next two chapters. But the principal reasons the Stern Review differs from most previous studies are:

- The choice of an ultra-low discount rate over an infinite time horizon,

- The treatment of uncertainty and risk giving significant weight to highly unlikely and very distant outcomes.

These are dealt with in later chapters.

28 In fact the review of existing economic literature is highly selective; for example, failing to mention the authoritative Report on The economics of climate change by the Lords Committee on Economic Affairs published in 2005.

29 The only study using broadly Stern's methodology is that of William Cline The Economics of Global Warming published in 1992, to which the Stern Review made no reference (until the Technical Appendix). (Unlike Stern, Cline makes allowance for the opportunity cost effect of using a sub-market discount rate.)

CHAPTER 3 – ESTIMATING THE IMPACT OF GLOBAL WARMING

"The Stoicks tell us, When the Sun and the Stars have drunk up the Sea, the Earth shall be burnt. A very fair prophecy: but how long will they be a-drinking?" - Reverend Thomas Burnet, 1691.

Estimating the amount of global warming and its impact if no action is taken to reduce emissions involves a series of steps, each requiring a number of assumptions and estimates.

• The first step is to project future concentrations of greenhouse gases – this requires assumptions about future population, economic growth, energy use, dependence on hydrocarbons, and the retention of greenhouse gases in the atmosphere.

• The second step requires an estimate of the changes in climate, i.e. the amount by which temperature will increase for a given increase in CO2 and other greenhouse gases, the changes in rainfall, storms, cloudiness, sea level and so on.

• The third step is to evaluate the impact climate change will have on the economy, society and human wellbeing. This requires estimates of how climate change will affect a host of variables, including the prevalence of diseases, crop yields, energy demand, species abundance etc, and how people, business, governments and markets would respond to that.

At every stage, a range of different estimates of each factor have been published in the literature which Stern reviews. Stern generally tends to adopt estimates and assumptions towards the pessimistic end of the range.

Step 1: Forecasting emissions and concentrations of greenhouse gases.

Future concentrations of greenhouse gases are affected by future growth in population, income per head, energy intensity of economic activity, the proportion of energy coming from hydrocarbons and the proportion of emissions which are captured and stored by the sea and plants. The IPCC does not predict a single path of future emissions of greenhouse gases. Instead it has depicted six broad scenarios – each reflecting different key variations. And within each of these six families it also describes a number of further variations, making 40 different scenarios in all.[30] In contrast, the Stern Review opts for a single scenario, and he selects the most pessimistic

30 Special Report on Emission Scenarios produced for the IPCC in 2000.

IPCC scenario, known as A2, with the second highest growth of emissions yet the lowest growth in incomes per head. This is because it assumes that population trebles from its current 7 billion to 21 billion (in 2150) whereas the UN central projection used in most other scenarios is that world population will peak at some 9 billion in the second half of this century. The subsequent IPCC Fourth Assessment admitted that the population scenario used by Stern

> "now falls above the range of recent projections from IIASA and the UN. This is a particular problem for population projections in East Asia, the Middle East, North Africa and the Former Soviet Union, where the differences are large enough to strain credibility. ... New scenario exercises will need to take the lower population projections into account".[31]

The huge growth in population that Stern assumes entails a rapid rise in total emissions even though incomes per head rise less rapidly than in other scenarios. Nonetheless, average income world-wide increases nearly four-fold this century and the gap between developed and undeveloped countries more than halves. His chosen scenario also assumes that economic growth remains energy-intensive and energy remains largely dependent on hydrocarbons, increasingly on coal. He ignores alternative scenarios, which assume that as reserves of fossil fuels are depleted their prices rise prompting a switch to alternative energy sources.

All the IPCC scenarios assume that the proportion of emissions which are absorbed in the oceans and by plants declines steadily. In fact, the proportion has been stable at about 45% for half a century.[32]

Table 2: IPCC Scenarios for growth in income (without global warming), population and temperature 1990–2100

		1990 actual	2006 actual	2100 scenario	2100 scenario	2100 scenario	2100 scenario
				A1F1	**A2**	B1	B2
GDP per capita	Developing countries	$900	$1,500	$66,500	**$11,000**	$40,200	$18,000
	Industrialised countries	$13,700	$19,300	$107,300	**$46,200**	$72,800	$54,400
World population				7.1 billion	1**5.1 billion**	7.0 billion	10.4 billion
Temperature change	1990 to 2090			4.0° C	**3.3° C**	2.1° C	2.4° C

Source: IPCC Special Report Emission Scenarios

NB – Stern uses scenario A2 with lowest income growth, highest population growth

31 IPCC AR4 Working Group III Ch3.2.1.1 Population Projections

32 IPCC AR4 Working Group II Ch7 notes that "From 1959 to the present, the airborne fraction has averaged 0.55, with remarkably little variation" but on the basis of theoretical models they project a decline in future.

and second highest global warming.

Step 2: Forecasting climate change

The fundamental science of the (enhanced) greenhouse effect is not disputed, even by those who argue that the impact of man-made emissions will be less than the IPCC forecasts. Without greenhouse gases – notably CO2 and water vapour - blanketing the earth, our planet would be a frozen rock at 18°C below zero. Adding more greenhouse gases will raise the temperature further but each successive increment has a diminishing impact. The IPCC believes that doubling the concentration of CO2 will eventually increase the average surface temperature by between 2.0°C and 4.5°C.

These are estimates of global averages. The temperature is expected to rise fastest the further from the equator and the further inland. Tropical and coastal regions will experience lower than average increases.

Stern assumes that sensitivity could fall outside the likely range assessed by the IPCC and, as emissions are expected to more than double, temperatures could rise by as much as 10°C or more. This is way beyond experience over the twentieth century and anything seriously predicted by the IPCC. We discussed more fully the treatment of risk and uncertainty in Chapter 4 and the Annex to it.

Step 3: Calculating damage caused by climate change

So how much harm would increases in global temperatures of the size envisaged by the IPCC cause?

Many people seem to assume that they would make life insupportable. Al Gore's film 'An Inconvenient Truth' and countless media depictions of cities submerged, floods, famine, tempest and disease have conveyed that impression. Governments have solemnly declared that any increase in average surface temperature above 2°C (since before the industrial revolution) would constitute "dangerous global warming". As the world has already experienced an estimated 0.8°C rise in temperatures since the industrial revolution, they are asserting that a further increase of a little over 1°C would be "dangerous".

Maybe. But such fears contradict our experience.

We are all used to changes in temperature far greater than anything predicted. We experience double-digit temperature changes between day and night, winter and summer and north and south of Europe. Far from finding higher temperatures intolerable, most people in Western Europe

prefer warmer climes. Every year millions of people voluntarily travel to holiday destinations often well over 10°C hotter than their home countries. Far fewer seek out cooler regions. And the hotter countries typically support far larger populations with less investment in adapting to the climate than do colder countries. Historically, periods of relative warmth (like the Roman and Medieval Warm Periods) appear to have been associated with growth in prosperity and the flourishing of civilisation whereas cooler periods (as in the European Dark Ages) have seen economic decline and social disruption. In general, there can be no doubt that humankind would find global cooling on any scale even more difficult to cope with than global warming. Most economic activity in developed countries (and Stern assumes currently underdeveloped countries develop over the next century) takes place indoors so is little affected by weather.

So a further increase in temperatures of just over 1°C, or even several degrees, would not of itself be intolerable. The direct effects of higher temperatures are comparatively modest. Predictions that global warming of this order of magnitude would be "dangerous" are based largely on the indirect effects such temperature rises might cause: like melting ice caps raising sea levels, more frequent and intense storms, increasing extremes of rain and droughts, shifting arid and monsoon zones and spread of disease. However, most extreme weather phenomena tend to be the result of temperature gradients across space rather than temperature levels.

There has been far less research into these effects than into the relationship between greenhouse gas concentrations and temperature, and there is even less consensus about them. As far as possible climate damage is concerned, it is meaningless to talk about "the science", still less to it being settled. It covers a huge range of possible phenomena from health to hurricanes. The impact of many of these can only be a matter of speculation since we have no direct experience of how temperature change will affect them.

The Stern Review first surveys the literature – invariably focussing on those studies which highlight the damages and downplay potential benefits of increased CO2 and higher temperatures. It then produces estimates of the aggregate cost via an 'Integrated Assessment Model', a computer programme comprising economic, climate and environmental impact models. Assumptions about future population, economic activity and energy use are fed into the economic model, which then estimates emissions of greenhouse gases; these estimates feed into the climate model, which then calculates changes in climate across the globe for centuries ahead; these are then fed into an 'impacts' model relating climate changes to their effect on the environment and human wellbeing. To the reader of the Stern Review, this model is a 'black box' - not least as far as the 'impacts' model is concerned. The Review gives no indication of which of the phenomena discussed in his review of the literature are actually assumed to occur and are incorporated into the model, let alone how much each contributes to the estimate of future damage.

However, although his quantitative conclusions are based on his model, Stern advises that:

> "… it is the underlying detail … rather than the aggregate models which should be the primary focus."

In other words, we should allow ourselves to be so frightened by the overall impression created by his partial selection of the most alarming studies that we take on trust the quantitative conclusions emerging from the model.

We therefore first examine the Review's account of the detailed impacts which it lists as: "access to food, water stress, health and well-being, and the environment".

Access to food

Most studies show that modest increases in temperature are likely to boost world food output in aggregate. Stern acknowledges that:

> "In cooler regions, low levels of warming may improve conditions for crop growth (extended growing season and new areas opened up for production)".

But he emphasises that:

> "further warming will have increasingly negative impacts as critical thresholds are crossed more often. Tropical regions may already be past the peak [optimum temperature] … depending on the crop."[33]

Not only are modest temperature increases on balance beneficial for crop yields, but a higher concentration of CO2 – the raw material of all photosynthesis – is universally good for plants. It not only stimulates photosynthesis but reduces water requirements by adjusting the size of pores in leaves. Stern admits that:

> "Research suggested that the positive effects of increasing carbon dioxide concentrations might compensate for the negative effects of rising mean temperatures".[34]

But he cites a recent study which halves the likely increases in crop yields from higher CO2 concentrations. Even the most pessimistic study he quotes, which assumes this weak carbon fertilisation effect, nonetheless predicts that a temperature increase as high as 4°C will only reduce yields by 10%. It concludes – though Stern again fails to report - that its simulations

> "demonstrate that the world, for the most part, appears to be able to

33 Stern Review page 71

34 Stern Review page 82

> continue to feed itself under the SRES scenarios during the rest of this century".

This assumes that farmers make only modest adaptations to higher temperatures using existing familiar plant varieties. It makes no allowance for improvements in yields as farmers adopt existing modern agricultural practices, let alone for the development of new agricultural technologies (including GM), new plant varieties more resistant to drought and responsive to higher temperatures etc. Yet the scope for this is enormous, which is why most forecasts, including all the IPCC scenarios, assume that world food production will outstrip population growth over the rest of this century.

Despite the pessimistic picture painted by the studies Stern selects, he implicitly assumes that total world food production more than keeps pace with a trebling of world population. Continuing improvements in agricultural methods and spread of best practices are (realistically) assumed to far outpace any difficulties caused by climate change. Since none of the IPCC scenarios envisages an overall food shortage, Stern focuses on the prospect of famine at a regional level, particularly in Africa and South Asia.

Global warming could hamper agricultural productivity in some parts of the world, particularly Africa, if it happened today. However, in Stern's scenario African economies grow rapidly, reaching middle-income status before temperatures have risen substantially. This is inconsistent with them facing famine. In the first place, it is hard to imagine rapid economic growth without substantial improvements in agriculture productivity. The scope for increasing yields is particularly great in Africa by adopting modern farming methods, water harvesting, fertiliser use, improved varieties etc. Second, even if shortages occur in particular years, middle-income countries would be able to import food rather than let their people starve.

Stern focuses particularly on the potential negative effects on crop yields of more extreme temperatures. He cites a study that he claims shows:

> "mean yields for some crops in Northern India could be reduced by up to 70% by 2100".

In fact, the study only covered a single crop – peanuts – which is not a staple crop. Stern does not report that the authors concluded:

> "The biggest drop in yield – of 70% - happens with a variety of peanut that is sensitive to high temperatures, that does not get enough rain and which grows quickly. But a peanut variety able to cope better with extreme high temperatures and which grows slowly at warmer temperatures could actually produce more peanuts in the 2080s than now."[35]

Tucked away in a footnote, Stern notes that the figures he is quoting "assume no adaptation". But surely it is reasonable to suppose that Indian farmers

35 Challinor, A.J., T.R. Wheeler, et al. (2006): '*Adaptation of crops to climate change through genotypic responses to mean and extreme temperatures, Agriculture, Ecosystems and Environment*'.

would switch to the variety that would actually increase their yields, rather than passively letting their yields decline by up to 70%? Stern's approach has been called 'the dumb farmer hypothesis'. His selective quotation of the results might be called 'the gullible reader assumption'.

Water stress

Stern emphasises the importance of water stress:

> "People will feel the impact of climate change most strongly through changes in the distribution of water around the world and its seasonal and annual variability."

He emphasises the numbers who will experience increased water stress – though a close reading reveals that a greater number will enjoy reduced water stress as a result of climate change. Moreover, his analysis is largely based on the work of Professor Arnell, whose study does "not include adaptation" (nor, indeed, economic growth and technological change) and therefore greatly exaggerates the negative effects of climate change. This leads to Stern including in his 'key messages' the example of Ethiopia, which

> "already has far greater hydrological variability than North America but less than 1% of the artificial storage capacity per capita … [which makes] the ability to adapt smaller."

The final phrase is a non sequitur. Developing more water harvesting and storage capacity is both the obvious method of adapting to climate change and what Ethiopia, like most of Africa, needs to do regardless of climate change, simply to realise its agricultural potential and increase food security. As it does so, it will be better able to cope with any increase in variability of rainfall resulting from global warming.

Health

The direct effect of temperature on human health is limited. Historically, humankind's main concern has been how to cope with winter cold – culminating in the spread of central heating in developed medium- and high -latitude countries in the last century. Warmer climates were more congenial and required less adaptation, which is why the bulk of humanity lives in tropical and semi-tropical countries where our species evolved.[36]

Nonetheless, there is a maximum temperature beyond which the human body cannot operate. This can perhaps be put at 50°C in humid conditions

36 40% of the world's population live in the tropics and a further 45% in subtropical areas. *The world by latitudes* by Matti Kummi and Ollis Varis Applied Geography 31 2011.

and 55°C in dry climate. Stern remarks:

> "Peak temperatures in the Indo-Gangetic Plain often already exceed 45°C before the arrival of the monsoon."

The implication is that if global warming were to result in peaks as high as 50°C, it would at least make work outside in daytime impossible and at worst threaten peoples' health. In today's India that would be the case. But over the next century – even without climate change - it is more than likely that air conditioning will become as prevalent in India as it already is in similar latitudes in America and as central heating is in temperate countries. Stern's analysis ignores that possibility.

The Review recognises that:

> "in Northern latitudes … global warming may imply fewer deaths overall, because more people are saved from cold-related death in the winter than succumb to heat-related death in the summer."[37]

But it goes on to cite figures for deaths from global warming, as if such net saving of lives will be offset elsewhere:

> "The World Health Organisation (WHO) estimates that climate change since the 1970s is already responsible for over 150,000 deaths each year. Just a 1°C increase in global temperature above pre-industrial [i.e. a further 0.2°C rise, as we have already had an estimated 0.8°C rise since the industrial revolution] could double annual deaths from climate change to at least 300,000 according to the WHO."

However, as Stern admits:

> "These figures do not account for any reductions in cold-related deaths which could be substantial".[38]

It turns out that the WHO figures are based on the essentially arbitrary assumption that some 2% of deaths from diarrhoeal diseases, malaria and malnutrition are the result of global warming that has already taken place. Even if this unlikely supposition were correct, it seems absurd to suggest we should transform the world's economy to save some 2% of the victims of these diseases when we could help save 100% of them at far less cost. In any case, these are diseases of poverty that can be, and generally are, progressively eliminated as an almost automatic consequence of normal economic development. Indeed, the WHO study assumes that climate change will have no impact on the incidence of these diseases in countries with GDP per capita above $6,000 – a level most are set to reach before long on Stern's 'business as usual' scenario for growth in GDP and energy use.

37 Stern Review page 87

38 Stern Review page 88

Sea level

The vision of rising sea levels drowning cities like New York and London is probably the iconic threat that dominates public fears of climate change. In fact, sea levels have been rising by about 2-3mm a year for at least a couple of centuries. Since the end of the ice age 18,000 years ago, the rise has averaged 67 cms per century. Man-made global warming can only be blamed for any recent acceleration in the rise in sea levels. The IPCC AR4 forecasts an increase of between 23 and 51cms this century for the A2 scenario chosen by Stern. This is a narrower band than the range from 9-88 cms predicted in the previous TAR report which Stern quotes. Some 57% of the rise in sea levels in recent decades is because water expands in volume as temperature rises. Melting of ice caps and glaciers accounted the remainder.

If the Greenland and West Antarctic ice caps melted, they would add, respectively, 7 and 5 metres to the sea level; the entire Antarctic ice cap would add 69 metres. However, the IPCC makes it clear that if that were to occur, it would not be over the next century or two but on "a millennial time scale".

The comparatively modest increases in average sea level expected this century are far from unprecedented. Not only has the average sea level been rising at a similar rate for centuries, but individual coastal cities have experienced and coped with subsidence of several metres, usually as a result of extraction of water from the subsoil. For example, Bangkok and Tokyo have subsided by 2 and 5 metres relative to sea level. More than a quarter of the Netherlands is up to 7 metres below sea level.

Stern nonetheless quotes:

> "one study that assumes protection levels will rise with GDP per capita, between 7-70 million and 20-300 million additional people will be flooded each year by 3-4°C of warming causing 20-80 cms of sea level rise".

Stern's wording is misleading: the upper end of the range is without adaptation, the lower end with adaptation.[39]

A recent study by the World Bank of the costs of adaptation to climate change shows that even Bangladesh – the country most exposed to sea level rise - could adapt to the increased threat of cyclones and storm surges due to climate change up to 2050 at an annual cost rising to barely 1% of GDP.

39 Nicholls and Tol (2006). The Stern Review does discuss adaptation, but this discussion is separated from its discussion on the impacts of climate change and from its discussion on optimal climate policy.

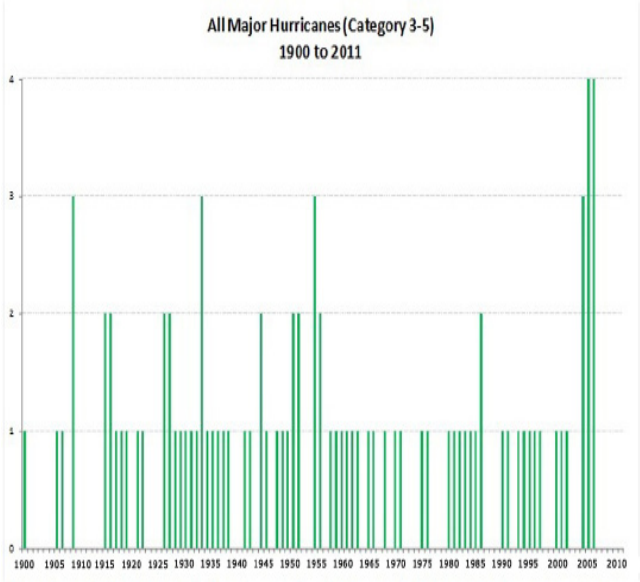
Infrastructure

Stern reaches estimates[40] of future losses from storm damage to buildings and infrastructure based on a highly tendentious[41] reading of a non-peer reviewed study.[42] This extrapolates a trend in insurance losses (which mainly reflect the growth in wealth, population, property etc). Stern quotes the trend between 1970 (which was a historically low year) and 2005 (which includes the cost of hurricane Katrina's impact on New Orleans). He ignores the fact that the study also shows that over a longer period – 1950 to 2005 - there is no upward trend in storm-related damages. The damage caused by Katrina cannot be attributed to climate change. But Stern effectively does so, saying it was

> "in large part driven by the exceptionally warm waters of the Gulf (1-3°C above long term average)".

Hurricanes of similar or greater power at landfall average about one a year but rarely hit such a critical point. Hurricanes inflicted similar damage on New Orleans in 1915 and 1947 which no-one attributes to global warming. Far from becoming more frequent, after two exceptionally severe hurricanes in 2005/6, there has recently been the longest period for a century without a Category 3 hurricane making landfall in the United States.

Figure 2: All Major Hurricanes (Category 3-5) 1900 to 2011



Source: National Weather Center NOAA, Technical Memorandum NWS NHC-6

40 "The costs of climate change for developed countries could reach several percent of GDP as higher temperatures lead to a sharp increase in extreme weather events and large-scale changes." (Stern, 2007, p.137).

41 *Mistreatment of the economic impacts of extreme events in the Stern Review Report on the Economics of Climate Change* Roger Pielke Jr Global Environmental Change 17 (2007) 302–310

42 Muir-Wood, R., Miller, S., Boissonade, A., 2006. *The search for trends in a global catalogue of normalized weather-related catastrophe losses. Workshop on climate change and disaster losses: Understanding and attributing trends and projections.* Final Workshop Report.

A recent World Bank study[43] strongly rejects Stern's estimates. It concludes:

> "The additional impact of climate change … is equivalent to 0.01 percent of GWP [in 2100]. These values are completely consistent with estimates in the literature per extreme event. However, they are completely inconsistent with values stated by Stern (2006) who suggests that extreme event damages could be 0.5 to 1.0 percent of GWP by 2050. Oral statements by Lord Stern even suggest values as high as 5 percent of GWP by 2200. The Stern analysis has been criticized because it confuses changes caused by what is in harms' way (baseline changes) with what is caused by climate change (Pielke 2007b). But even this mistake cannot justify the estimates by Lord Stern. The hypothesized damages quoted by Lord Stern are completely inconsistent with empirical evidence."

Where the numbers come from

Although the Review enumerates a whole range of alarming estimates of different forms of harm that global warming could cause, its total cost estimates are not calculated by simply adding these together. Nor could it be, given their disparate time scales, metrics and coverage.

Instead, the total cost estimate comes from a fairly simple equation embedded in the PAGE2002 Impact Assessment Model. The model is given a range of assumptions of impacts on the GDP of each geographic area for a 2.5°C rise in temperature. Thus, the first 2.5°C temperature rise is deemed to reduce GDP in India by between 1.5 and 4 times the loss in the EU (where the median loss is put at 0.5% of GDP). The loss is then set to increase as a power of temperature ranging between linear and cubic - averaging 1.3.

Additional assumptions are made about the effect of temperature on non-economic factors, again expressed as a percentage of GDP and a proportion of losses – lower in less-developed countries - is assumed to be prevented by adaptation.

Of necessity, these assumptions are all essentially arbitrary. They are supposed to reflect a combination of factors from flooding to disease in a single output from the equations. In this respect, Stern's approach is no different from any of the others using integrated assessment models. However, it should be born in mind that assertions that the conclusions are all based on 'known science' do not apply to this essential step in the process – putting a value on the damage likely to be inflicted by global warming. There is no overarching scientific theory relating damage to temperature changes – only a patchwork of hypotheses about how different aspects of life might be affected.

One crucial difference between the models and the alarming picture

43 Robert Mendelsohn & Gokay Saher *The Global Impact of Climate Change on Extreme Events* World Bank Policy Research Working Paper 5566 Feb 2011.

painted by the studies is that the model has to assume that all forms of damage happen simultaneously and immediately the temperature increases. Yet we know that once the temperature has risen sufficiently to start melting the ice caps it will take millennia for them to disappear. So Stern's model is presumably advancing its impact by thousands of years.

CHAPTER 4 - COSTS OF RESTRICTING EMISSIONS

That Stern's estimate of the damages of global warming was so far above the consensus was not the only surprise in his Review. Equally surprising was how much lower than the consensus was his estimate of the costs of reducing emissions.

Stern concluded that the cost of stabilising emissions at his target could be limited to just 1% of GDP by 2050. That was below the bottom of the range of Stanford University's Energy Modelling Forum, whose average was 2.2% of GDP. Moreover, that group of 21 model estimates calculated that the cost would rise to 6.9% of GDP by 2100. Stern did not project costs beyond 2050 – ignoring any subsequent escalation as further reductions in CO2 emissions become increasingly costly.

Rather embarrassingly for the British government, it was subsequently obliged to produce for Parliament its estimates of the costs of its Climate Change Act (which enshrined in law targets to meet Stern's objectives), which also exceeded Stern's estimate. The Impact Assessment estimated a permanent loss of 1.6% (or in the range 1-2%) of GDP from 2050 onwards. It put a net present value of up to £400 billion (or £18 billion pa before discounting) on the cost of mitigation up to 2050[44] but admitted that this excluded the transitional cost which it said could average a further 1.3-2% of GDP up to 2020, not to mention the cost of driving British carbon-intensive industries overseas, the risk of which the IPCC found to be "relatively high" and could result in leakage of 5-20% of carbon savings overseas.[45] Ignoring these costs, the Impact Assessment was able to conclude that the costs are

> "consistent with the range of costs identified by the Stern Review - 1% of GDP by 2050, within a range of +/- 3%".

However, with

> "short and medium run (i.e. to 2020) transition costs could be in the upper end of the range indicated by the Stern Review".

The Stern Review made no attempt to estimate the cost and effectiveness of measures to reduce carbon emissions already undertaken in the UK and elsewhere since the Kyoto Agreement. Instead, Stern's estimates are based on a projection of future costs by Dennis Anderson, commissioned for the Review. Sadly, Professor Anderson – a respected expert in this field – has died since the Review was published so it is not possible to clarify a number of

44 Climate Change Act 2008 Impact Assessment March 2009. The assessment bizarrely puts no value on loss of GDP after 2050, whereas it uses a Social Cost of Carbon to calculate the costs of global warming which appears to be based on future impacts projected into the indefinite future

45 IPPC (2001) Third Assessment Report, using Computational General Equilibrium models with exogenous technological change, estimated leakage rates for the first Kyoto period through uniform carbon taxes of between 5-20%. Babiker (2005) produced much higher leakage estimates, ranging from 25 to over 100%; implying significant losses of competitiveness for OECD countries.

puzzling features of his study.

It is not clear how fully he takes into account the costs of replacing existing capital stock. For example, a power plant can last for decades before being replaced. So it would be hugely costly to replace existing capacity ahead of its natural life with new low-carbon technology. Anderson confirmed in private correspondence with Tol that capital turnover was taken into account – though those costs do not appear to have been considered in setting the Review's strategy for reducing emissions. It also remains unclear to what extent the study included the cost of building the complementary infrastructure required for new technologies. For example, if all power stations were fitted with Carbon Capture and Storage, it would be necessary to build a pipeline network comparable to the existing oil and gas pipeline networks.

Undoubtedly, there is scope for improved energy efficiency – not least given the incentive of higher oil prices. World energy consumption rose by 5% pa between 1950 and the first oil shock in 1973, then stabilised until the early 1980s, since when it has grown by less than 2% pa despite the rise of China and others.[46] Recent increases in oil prices are likely to accelerate the shift to more efficient and lower carbon technologies, even on a Business As Usual basis. Savings beyond those, which will happen anyway, will be more costly and difficult to achieve. It is not clear whether the Stern Review has adequately allowed for this.

The Review also prays in aid the International Energy Authority estimates of the cost of reducing emissions which are of a similar order of magnitude to its own. Key features of Anderson's projections are: he assumes that solar energy will contribute some 15% of carbon reductions – slightly more than nuclear energy. Largely because of his high estimate for solar energy, Anderson projects a far higher contribution from renewables (40%), as well as nuclear, than does the IEA (15%). Both Anderson and the IEA rely on a major contribution from Carbon Capture and Storage – 15% and 20% of savings respectively - and the IEA is particularly optimistic about the scope for savings from energy efficiency, which account for no less than 46% of carbon savings in its main scenario against 25% for Anderson.

A weakness of Anderson's study is that he assumes that if a technology is possible it will be delivered at its assessed cost. Experience suggests this is unduly optimistic. Nuclear power proved far more costly than anticipated.[47] In its infancy, it was hailed as promising electricity 'too cheap to meter' but proved barely competitive with conventional fossil fuel power stations. And nuclear fusion, which was expected to be providing electricity within 25 years when the Zeta project was launched in 1954, is still a distant dream. Likewise, confidence in fast breeder technology was sufficient to justify the construction of the Dounreay reactor but has not been borne out there or across the world.

46 BP Statistical Energy Review 2011

47 Dieter Helm Energy the State and the Market 2003 OUP

Anderson and Stern are also optimistic about the speed with which costs of new technologies will come down. Stern quotes a study[48] showing the cost of generating electricity from coal in the UK has declined ten-fold since 1891. Much of that came in the early decades and over the last half century the amount of coal needed to generate a unit of electricity has declined by just half. Whether the early cost reductions in wind and photo-voltaics will continue or also slow down remains to be seen. Stern hopes that extra R&D, as well as 'learning by doing', will accelerate their approach to competitiveness. Let us hope so. But it is important to realise there is an opportunity cost in this. Resources devoted to developing less costly low-carbon technologies could have been used to reduce costs in some other sector of the economy. This does not appear to have been taken into account in the costing of emission reductions. Nor has the likelihood that the cost of energy production from fossil fuels will also continue to decline, albeit at a modest pace, as it has over the past half century. So, new energy sources are chasing a moving target. For example, the recent exploitation of shale gas has dramatically reduced gas prices in the United States - and, as it happens, has cut CO2 emissions in America far more than all the investment in expensive renewables in the European Union.

However, if the Review is correct, and the costs of alternatives are set to fall rapidly over the next few decades, it would be foolish to invest too much too soon in as yet immature technologies. Stern recognises this:

> "The lesson here is to avoid doing too much, too fast, and to pace the flow of mitigation appropriately."[49]

However, he only deploys that reasoning to argue against the even more rapid cuts needed to stabilise emissions at a more ambitious target than the 500-550 ppm he advocates. He says model comparisons show that to stabilise at 450-500 ppm would cost three times as much. But he dismisses the idea that a slower path to a less ambitious stabilisation target would materially reduce costs.

Any crash programme to reduce emissions would put huge strains on the world's industrial capacity. It is doubtful whether we could speedily produce the extra cement, steel etc. it would require. Each nuclear power plant needs a huge 'kettle'. Only a handful of companies possess the technology and capacity to manufacture them and their existing order books are full for many years ahead. Ramping up construction of large numbers of nuclear power stations would drive up costs dramatically. This is exactly what happened when Germany's generous subsidies for solar power sharply increased demand for pure silicon, driving up its price nearly ten-fold, to the advantage of the largely Chinese suppliers.[50]

48 Hannah L. (1979) *'Electricity before nationalisation: a study of the development of the electricity supply industry in Britain to 1948'*. The John Hopkins University Press.

49 Stern Review page 276

50 The Economist 28th August 2008 *One shortage in the solar panel business gives way to another*.

At present, energy produced from most low-carbon technologies is not marginally, but several times, more expensive than from fossil fuels.

Solar power

Solar power may be a viable contributor to energy supply in countries endowed with constant direct sunshine. However, it is among the most costly alternatives in a European climate. Germany and Spain, which both offered generous feed-in tariffs to encourage domestic and commercial owners of solar panels to feed electricity into the grid, have recently reined back their subsidy regimes. Germany found it was paying out 14 billion Euros annually for feed-in tariffs, mainly for solar electricity which met just 3% of its electricity demand. That did not stop the British government introducing, in 2009, a similarly generous feed-in tariff. The government's own Impact Assessment calculates that the likely cost (£8.6 billion over twenty years) is twenty times greater than the potential benefit from reduced climate change damage (which it puts at £400 million). Even the arch campaigner against man-made global warming – the Guardian's George Monbiot – was moved to describe this absurdity as "the definitive example of a great green rip-off ... The government is about to shift £8.6bn from the poor to the middle classes" by transferring money from the pockets of poor taxpayers to rich owners of solar panels. It is particularly alarming that the Stern Review envisages solar energy providing 15% of carbon savings by 2050. It seems to have escaped their notice that, apart from the technology being extremely expensive, the sun is not available in much of the world when it is most needed – at night and in the winter. Consequently, it must be backed up with conventional power stations.

Wind power

Wind power, too, is intermittent and requires conventional back up. In 2010, onshore wind turbines in the UK operated at 22% of their full capacity, offshore at 30%. Jevons pointed out nearly a century and a half ago why coal had ousted wind:

> "The first great requisite of motive power is that it shall be wholly at our command, to be exerted when, and where, and in what degree we desire. The wind, for instance, as a direct motive power, is wholly inapplicable to a system of machine labour for during a calm season the whole business of the country would be thrown out of gear."[51]

Because wind is unpredictable, back-up power stations need to be running on idle even when wind turbines are feeding into the grid. The UK government assumes that the variability of wind power only increases

51 William Stanley Jevons *The Coal Question* (1865), p. 122

carbon emissions by conventional back-up power stations by 100,000 tons of carbon, against savings of 5.5 million tons from wind itself.[52] This looks barely credible. According to a recent study:[53]

> "the UK Government's target for renewable generation in 2020 will require total wind capacity of 36 GW backed up by 13 GW of open cycle gas plants plus large complentary investments in transmission capacity. The same electricity demand could be met from 21.5 GW of combined cycle gas plants. ... Under the most favourable assumptions for wind power, the Wind Scenario will reduce emissions of CO2 relative to the Gas Scenario by 23 million metric tons in 2020 - 2.8% of the 1990 baseline - at an average cost of £270 per metric ton at 2009 prices. If this is typical of the cost of reducing carbon emissions to meet the UK's 2020 target, then the total cost of meeting the target would be £78 billion in 2020, or 4.4% of projected GDP, far higher than the estimates that are usually given."

Carbon Capture and Storage (CCS)

Stern accepts that fossil fuels will continue to supply some 75% of electricity in 2050. So he puts his faith in the speedy development of this technology which so far has not been tried and tested. What is known is that CCS requires a great deal of energy – equipping a power station with CCS is likely to increase its coal consumption by as much as 25% to produce a given amount of electricity. It is hard to envisage China, for example, adopting this technology any time soon, even if it can be made to work. China consumes annually some 3 billion tonnes of coal, until recently supplied from its domestic mines, though it has just become a net importer. By 2020 its consumption is expected to double, with half being imported. So if China fitted CCS to just one-third of its coal-fired plants, it would increase its coal usage and imports by up to 500 million tonnes – scarcely likely.

Bio-fuels

Bio-fuels are one of the few technically viable alternatives to hydrocarbons for use in transport. The EU has set a target that 10% of transport fuels should be bio-fuels by 2020. Stern expects them to meet some 13% of carbon savings globally. However, Stern acknowledges that to produce them on the scale required would divert an area of land equal to that of France and Spain – 10% of all arable land world-wide.[54] In 2009, 25% of US grain crops were used for ethanol to blend with gasoline. The diversion of land to producing bio-fuels has already contributed to high world food prices – a concrete example of sacrificing the interests of today's poor for

52 Hansard replies to PBL 25th Jan 2011

53 *Why Is Wind Power So Expensive? An Economic Analysis* Gordon Hughes, GWPF Report 7

54 Stern Review page 256

the supposed benefit of richer future generations. In the medium-term, growing use of bio-fuels will also add to pressure on forest land, even though deforestation already accounts for some 20% of CO2 emissions world-wide. Bio-fuels typically cost around twice that of transport fuels from fossil sources. There are also doubts about the extent to which bio-fuels actually reduce net carbon emissions. Leaked figures[55] from an EU study show that if induced land use loss is included, the net carbon emissions from palm and soy oils are nearly equal to those of tar sands; even the more efficient sources, like US corn oil and Brazilian sugar cane, still emit respectively a half and a third of the emissions from crude oil. Environmentalist groups like Friends of the Earth now oppose their use, claiming they will cost EU consumers up to €126 billion[56] without reducing emissions.

Nuclear energy

Nuclear energy is the only source of electricity which is technically available and of comparable cost to fossil fuels. Overall competitiveness depends on the cost of decommissioning plants, which will be determined largely by regulatory considerations prevailing at the end of their useful lives. Nuclear plants are most economic as source of base load but, as they cannot be readily turned on and off, they need to be complimented by conventional fossil fuel (or hydro) generators to provide the variable load.

Efficiency

Increasing energy prices – whether as a result of rising costs of fossil fuels as less costly reserves are exhausted or because of green taxes – should result in increasingly efficient use of energy. However, it is optimistic to suppose that this factor alone will generate the 25% of carbon savings foreseen by Anderson, let alone the 46% envisaged by the IEA.

Stern's cost estimates rest on two mutually contradictory assumptions about the behaviour of markets.

On the one hand his costing assumes that, once the price of hydrocarbons incorporates the social cost of carbon emissions, companies will universally, instantly, optimally and with perfect foresight of future technological developments adopt the most effective low carbon technologies as they become available. The government's Impact Assessment of the Climate Change Act made the same assumption explicitly – "modelling assumes perfect foresight about the future availability of technologies".

Even economists who believe that markets are generally the best way to ensure resources are used most efficiently recognise that in the real

55 *Biodiesels pollute more than crude oil, leaded data show.* EurActiv 27 January 2012

56 *The bad business of biofuels.* Friends of the Earth Europe. February 2012

world it takes time for new technologies to be adopted universally. New technologies do not suddenly appear in final form, costed and proven. So it takes time for them to be tried, tested and adapted, for information about them to be disseminated and for the forces of competition to compel their adoption. On top of which it may not be efficient for those who have sunk costs in existing technologies to adopt new technologies until existing plant needs replacement. So Stern's costings almost certainly exaggerate the savings and understate the costs of introducing new more efficient energy sources.

On the other hand, Stern's costings appear to assume that markets do not make optimum use of existing technologies. He assumes that there are potential savings available which companies and individuals currently ignore. His range of costings of reducing emissions is -1% to 3.5% of GDP. Negative figures imply that largely decarbonising the world economy could actually cost less than continuing to use fossil fuels. This is partly because some of his projections assume the cost of low-carbon technologies rapidly falls below that of fossil fuels – an assumption which requires both heroic optimism and ignoring the continuing improvements in efficiency in conventional energy generation. But it is mainly because the estimates assume there is substantial scope for using energy more efficiently. Even Stern's mid-range cost estimates assume substantial efficiency savings of this kind, albeit not sufficient to offset fully the higher cost of low-carbon technologies. Most of these opportunities for efficiency saving are assumed to exist already but people and companies have failed to exploit them even though, by definition, it would be profitable to do so.

No doubt there are some companies and individuals who fail to recognise and exploit opportunities to reduce their energy costs despite their profit incentive to do so. But one must be somewhat sceptical when a handful of desk-bound economists claim to be able to identify so easily profit opportunities on a massive scale which have escaped the notice of those with an incentive to exploit them.

This ambivalence towards the operation of markets feeds through to Stern's (and the British government's) policy prescriptions. If markets and the price mechanism are the best way to utilise information and resources efficiently then the key is to price in external costs. Stern describes the fact that fossil fuel prices do not reflect the costs he believes carbon emissions will impose on humankind as "the greatest market failure the world has ever seen". He concludes, logically, that

> "Three elements of policy are required for an effective global response. The first is the pricing of carbon"[57] so that "The carbon price should reflect the social cost of carbon".[58]

Businesses, farmers, families and government agencies will then have the

57 Stern Review page xviii.

58 Stern Review page 261

appropriate incentive to economise on use of fossil fuels and develop and switch to low-carbon alternatives.

There are two ways to price in the social cost of carbon:

• either ration the amount of carbon that may be emitted and let people buy and sell entitlements to emit carbon, leaving the market to set the price of carbon. This is the approach of the EU Emissions Trading Scheme and Obama's now defunct Cap and Trade Bill.

• or set the carbon price at an appropriate level such that the market curbs emissions to the optimum level. This involves setting a Carbon Tax at a value equal to the social cost of carbon emissions.

Similar choices between rationing quantities and setting prices are faced in a number of situations. A seminal study by Weitzman[59] analysed the circumstances in which each instrument - pricing or rationing - will be superior. Applying that analysis to the issue of controlling greenhouse gas emissions shows that pricing (i.e. imposing a tax) is much superior to rationing (i.e. selling emissions quotas).[60]

Likewise, economic analysis indicates the path such a tax should follow to ration emissions over time such that they cumulatively result in a maximum concentration in the atmosphere equal to the stabilisation target. Paradoxically, the problem is (nearly) identical to the problem of how rapidly a theoretically finite natural resource like petroleum should be depleted. It was established that depletion would be optimised by allowing the price of the scarce resource to rise in line with interest rates. In the case of climate policy, instead of depleting the earth's stock of oil it is claimed that we are gradually using up the maximum capacity of the atmosphere safely to accumulate greenhouse gases. So, by analogy, the cost of carbon emissions – including the social cost of carbon - should be set to rise over time at a rate equal to the long-term interest rate.[61]

If a choice must be made between a carbon tax and an emission trading system, the former would be preferable since:

• As well as being economically more efficient, a carbon tax is much less susceptible to fraud and manipulation than is rationing/carbon trading. Existing emissions trading schemes have already been marred by grotesque examples of fraud. Moreover, governments have been unable to resist the temptation to use their power to allocate emission rights to benefit politically favoured or powerful recipients at the expense of the rest. That is probably one of their principal attractions to politicians. The result has been an

59 *Prices versus Quantities* Martin Weitzman, Review of Economic Studies 1974

60 *Prices versus Quantities Revisited: the case of climate change.* William Pizer Discussion Paper 98-02 Resources for the Future Oct 1997 Pizer estimates the welfare gain from tax/pricing option would be five times that from emissions rationing.

61 *The Economics of Exhaustible Resources,* Hotelling. Journal of Political Economy April 1931. The carbon emission problem is slightly different because a proportion of emissions is absorbed by the oceans and biosphere. In practice, taking this into account results in a negligible deviation in the optimum path from one set to rise in line with interest rates.

allocation lacking any rational economic basis. Existing heavy energy users have received large allocations free; other firms receive allocations in excess of their needs as a form of subsidy; allocations to existing companies act as a barrier to new entrants. Governments have been tempted to issue more allocations than warranted by the targets, driving prices of carbon credits down to levels which offer little incentive to reduce emissions.

• It renders unnecessary the battery of special regulations, controls and subsidies. If companies face a cost of emissions which reflects the full social costs that those emissions are expected to impose, they do not need other incentives to take them into account.

• A carbon tax can be imposed at the limited number of points at which carbon enters the economy rather than the millions of points at which emissions are made. So it is administratively simpler than emissions trading. Moreover, it would be easier to monitor whether countries who sign up to international agreements have implemented them than in the case of a trading system.

However, instead of adopting either a steadily rising carbon tax or a progressively reducing ration of emission permits, Stern endorses a mix of these together with a battery of subsidies, targets for specific renewables, controls and regulations. A recent report[62] spells out how these inevitably raise the cost of achieving a given level of emission reductions. If renewables were the most cost-effective way of reducing emissions there would be no need to impose a specific target in addition to a carbon tax or emission quota. However, the Renewables Obligation for energy utilities is vastly more costly than alternative means of carbon reduction at this stage. The study puts the cost of the Renewables Obligation at £130 per tonne of CO2 saved whereas the marginal cost of carbon reduction is said to be only £14 per tonne under the technology-neutral EU Emissions Trading Scheme. Indeed, the Renewables Obligation depresses the ETS price, disincentivising cheaper carbon reduction measures. It also puts up the cost of electricity, deterring the electrification of other sectors which would be necessary to meet the overall decarbonisation target. Rather than setting an example to the rest of the world, a policy which involves high costs for limited gains is likely to put them off.

62 *2020 Hindsight: Does the renewable energy target help the UK decarbonise?* Simon Moore. Policy Exchange 2011.

Chapter 5 - Discount Rate

"The conclusion I have reached is that the strong immediate action on climate change advocated by the [Stern Review] is an implication of their views on intergenerational equity; it isn't driven so much by the new climatic facts as the authors have stressed." Professor Das Gupta.

Discount rates are crucial

The impact of global warming is projected to unfold over centuries or even millennia. The Stern Review predicts that costs of global warming – if we take no action to reduce emissions – will rise faster than GDP until 2200 and thereafter continue to rise in line with GDP forever and ever[63], world without end! By contrast, the cost of reducing emissions starts now. We therefore need to compare future damages from global warming into the indefinite future with the cost of taking action in the coming decades to prevent it.

The rate at which future costs and benefits are discounted is crucial. Table 2 below shows how much £100 in 2012 would be worth in 2112 and 2212 if discounted at different rates.

Table 3: Present value in 2012 of £100 in 2112 and 2212 discounted at different rates

Discount Rate	Present Value of £100 in 2112	Present value of £100 in 2212
% per anum	£	£
0.1	90	82
1.0	37	14
1.4	25	6
3.0	5	0.3
6.0	0.3	<
10.0	<	<

Source: Author's calculations

In its 700 pages, the Stern Review does not reveal the discount rate used even though this is its most crucial assumption. It was not until some time after publication and as a result of strenuous enquiries, that it emerged that

63 This assumption is physically impossible. If fossil fuel resources are assumed to be finite, and global warming is proportional to the natural logarithm of carbon dioxide concentrations, climate change must slow down in the very long run even if no policies are introduced to reduce emissions. Assumptions about what happens in the very long run are highly uncertain, and relevant only with a low discount rate.

the Review uses a discount rate of just 1.4% pa.[64]

This is far lower than rates typically used in most previous studies or the discount rates used by businesses, governments, the World Bank etc. It is the main reason the Stern Review's conclusions are out of line with those of most other studies.

Since publishing his Review, Stern has indicated[65] that, on reflection, he would now use a discount rate almost double. This would dramatically scale down his headline figures. This volte face received predictably little coverage. Yet according to the Review's belatedly published sensitivity analysis, the effect of doubling the discount rate to 2.8% pa is to reduce his base case estimate of the amount by which unrestricted global warming would reduce global GDP from 5% to 1.4%, 'now and forever'. Using a discount rate of 2.8% pa in Stern's most gloomy case reduces his central estimate of loss of GDP from 14.4% to just 4.2% 'now and forever'.[66]

The effect of using the Stern Review's low discount rate is to give huge weight to events in the distant future which are assumed to be the ineluctable consequence of actions taken by this generation. Estimates by Tol and Yohe using Stern's model suggest that nearly half of all damage the Review attributes to global warming relates to events more than two centuries ahead. Using different assumptions, Nordhaus has estimated that, under Stern's methodology, half of all benefits of preventing global warming will accrue to generations living after 2800![67]

Market rates of return

Typically, businesses and governments discount the future using the rate of return that could be obtained on alternative investments – usually assumed to be the average return on capital in the market place.

Thus the US government uses 7% pa. The recommended UK government rate used to be 6% pa until 2003. It was then decided that potential social benefits justified using a lower figure of 3.5%[68] (declining to 3.0% after 30 years, to 2.0% after 125 years and to 1.0% after three centuries[69]). Returns available in the market differ from country to country, but it is a useful hurdle against which to judge any investment: why should anyone invest in

64 That is the figure now acknowledged by the Review authors, though the picture is more complex according to a personal communication between HM Treasury and Christopher Monckton that the study assumes annual growth rates of 2.0% this century, 1.7% next century and 1.3% thereafter so the discount rates used are 0.1 percentage points higher.

65 Stern The Economics of Climate Change, Ely Lecture, American Economic Review: Papers & Proceedings 2008. See Annex to this chapter for a discussion of the issues involved.

66 Technical Annex to Postscript to Stern Review Table PA.3.

67 "In fact if we use Stern's methodology, more than half the estimated damages 'now and forever' occur after the year 2800": Nordhaus *A question of balance* 2008

68 The Green Book: Appraisal and Evaluation in Central Government HM Treasury July 2011

69 "However, such a decline may be less significant than it looks; the first few decades of discounting at higher rates are the most important in terms of evaluation of future costs and benefits." Ackerman *Debating Climate Economics: The Stern Review vs. Its Critics* Report to Friends of the Earth-UK July 2007

a project – be it preventing global warming or anything else – if they can obtain a better return (including social, environmental and other non-market benefits) elsewhere?

That provides a practical reason for using the market rate. But it could be argued that discount rates are intrinsically subjective. How each person values the future benefits relative to present costs depends on their individual preferences, circumstances and expectations. It would be easy to conclude that:

- We all have different discount rates,
- The market rate is at best the average of people's discount rates,
- So Stern is entitled to his view about what discount rate should be used.

However, each of these points needs to be qualified. Everyone will start with their own subjective trade-off between marginal future benefits and current costs. But to the extent that people are free to save and invest or to borrow and spend, their marginal discount rate will converge to the market rate of return because anyone who starts by discounting their future consumption at a lower rate than the market rate of return will find it attractive to save, lend and invest in the market. They will continue to do so until they have depressed their current consumption and raised their prospective consumption to the point where the marginal cost to themselves of any further reduction in current consumption in order to save equals the value they put on the return on that extra saving.[70] Their additional saving will also tend to depress the market rate of return as investors undertake less attractive investments. Thus personal discount rates and the market rate of return will tend to converge. Conversely, those who start by valuing the present very highly will find it attractive to borrow to spend now until the need to repay loans depresses the level of future consumption sufficiently to make further borrowing unattractive. At that point their discount rate will have converged on the cost of borrowing which is the market rate of return.

In short, far from everyone having a different subjective discount rate, they will all converge with the market rate of return. So the latter is not just the average, but the consensus rate of discount. This is a compelling theoretical reason for using it if we wish to reflect other people's views rather than impose our own.

Stern is still entitled to use his own discount rate – but only if he faces up to the implications of having a different rate of discount from the rate of return available in the market. This he fails to do, which has serious implications for the valuation of investments to reflect the opportunity cost of investing elsewhere and also the optimum level of saving and investment. These issues are discussed below.

70 *The principles of practical cost-benefit analysis* by Robert Sugden and Alan Williams p16.

Stern's Discount Rate

Stern rejects the market rate on three grounds:

- because there are no capital markets spanning centuries, evidence from shorter time spans may be inappropriate. He does not explain why people would not simply project over longer periods much the same rates that they already use to span several decades – to do otherwise would lead to inconsistencies. At very least, he could have used market rates for the next 30-40 years, which do exist, before applying his much lower rate of 1.4%.

- since markets are imperfect, they cannot provide guidance on people's actual discount rates – though he does not explain why imperfections should imply that observed discount rates are too high, rather than too low.

- because he believes the consensus views reflected in the market rate are irrational and unethical.

Instead of using a discount rate based on what people actually do, Stern says policy makers should use a rate based on what people ought to do. So he seeks to derive a discount rate based on first principles of rationality and ethics. He draws on the analysis (discussed more fully in the annex to this chapter) of the mathematician/economist Frank Ramsey. Ramsey analyses two reasons[71] why people discount future costs and benefits: the passage of time and the fact that they may value a marginal change in their consumption differently if it occurs when they have a different level of consumption.

Discounting for time

Discounting for time – known to economists as 'pure time preference' - is, says Stern, irrational and unethical. He quotes Ramsay, who says we should not

> "discount later enjoyments in comparison with earlier ones … a practice which is ethically indefensible and arises merely from the weakness of the imagination".[72]

Other economists have made much the same point. It is deemed to be irrational because – unless our circumstances change - we should logically put the same value ('utility') on a given change in our consumption whenever it occurs. And it is felt to be unethical because we should put the

71 He does not tackle a third reason – uncertainty – as his model assumes people have perfect foresight. Uncertainty is considered in the next chapter.

72 However, even Ramsey did not apply this logic to his own world view. He subsequently wrote "In time the world will cool and everything will die; but that is a long way off, and its present value at compound interest is almost nothing." In *The foundations of mathematics and other logical essays* Ed Braithwaite 1931.

same value on a cost or benefit incurred by others – even if they are distant in time – as we would if it affected us in identical circumstances. As Stern puts it:

> "We take a simple approach in this Review … a future generation … has the same claim on our ethical attention as the current one."

Those who disagree are dismissed as "reckless" or "unethical"; they

> "simply do not care much for what happens in the future beyond the next few decades …"[73] (This ethical imperative is considered further below).

In short, although most of us do in practice – irrationally in Stern's view – discount our own future consumption, we should not discount the consumption of future generations however distant they may be. We, or rather the government on our behalf, should care more about the consumption levels of future generations than we in practice care about our own future well being!

Unfortunately, Stern's assertions about treating future well-being according to his standards of rationality and ethics would, on their own, have unacceptable consequences. They imply a zero discount rate for time. That would mean that we should put the same value on the projected impact of climate change on people thousands of years hence (differences of income apart) as if it affected ourselves today. Moreover, Stern projects the impact of emissions to infinity, yet discounting to infinity at a zero rate would put an infinite value on even the smallest reduction of emissions. Most economists have rejected the use of a zero rate of time preference over an infinite horizon because of this 'reductio ad absurdam'.[74] Possibly they also dismiss it because projections into the distant future have declining credibility. Projecting to infinity can be useful for theorising but, prior to Stern, hardly anyone had proposed using a zero discount rate for time over an infinite horizon for empirical studies.[75]

Although Stern does not acknowledge that his the motive was to avoid the unacceptable result of tiny benefits having an infinite present value, he had to include some positive discount rate over time, however small. He therefore introduces an arbitrary discount rate over time of 0.1% pa – justified as representing the risk of extinction (for reasons other than climate change e.g. collision with an asteroid, nuclear warfare or some as yet unforeseen disease or disaster).

73 Simon Dietz, Chris Hope, Nicholas Stern & Dimitri Zenghelis World Economics • Vol. 8 • No. 1 • January–March 2007 p121/2

74 They also imply a high level of saving which Ramsey acknowledged is "greatly in excess of that which anyone would normally suggest". Likewise Kenneth Arrow says "I therefore conclude that the strong ethical requirement that all generations be treated alike, itself reasonable, contradicts a very wrong intuition that it is not morally acceptable to demand excessively high savings rates from one generation, or even of every generation. We must accept that the pure rate of time preference is positive." *Intergenerational Equity and the rate of discount in long term social investment,* IEA World Congress 1995.

75 As Partha Dasgupta points out: "Models of a deterministic world with an infinite horizon are mathematical artefacts. They are meant to train our intuitions about economic possibilities in a world with a long, but finite, horizon, when we are loath to specify the termination date, and are also loath to acknowledge that it has an uncertain date." *Three Conceptions of Intergenerational Justice*. 2004.

His assumption about extinction corresponds to a 10% probability of extinction per century, which seems high as Homo sapiens did not become extinct in the past 2,000 centuries. Such a threat is surely more serious than climate change - which according to the Stern Review may cost one-fifth of our income, rather than all of our lives - and should therefore be prioritized.

Even a discount rate of 0.1% leads to some pretty mind boggling numbers. As Nordhaus points out: suppose that we knew for certain that one consequence of global warming, which would not even chip in until the year 2200, would reduce the wellbeing of generations thereafter by one thousandth. Discounted at 0.1% pa to the present day, that would be valued at some $30 trillion.[76] That is over half the world's annual GDP or 300 times the current world spending on overseas aid. Would it really be worth this generation foregoing that sum to make our immensely wealthy descendents imperceptibly better off? Might it not be better spent on today's poor?

Discounting for changes in income/consumption levels

Stern accepts that the richer people are, the less weight we should attach to a given benefit conferred on them by reducing the impact of global warming. This is based on the concept that the value ('utility') of additional income declines the better off the recipient. This reflects both the lower value most people put on extra consumption the higher their own level of consumption, and their preference for alleviating the poverty of the poor rather than making the rich richer. It therefore encapsulates society's 'aversion to inequality'. So, the richer we expect people to be in the future, the more we should discount the impact of global warming on them.

This is a fairly standard economic and commonsense view. But there is considerable debate about how much one should discount for higher levels of consumption. Stern decides to discount the effect of climate on future generations in direct proportion to the growth in their average incomes relative to today. If income is expected to double then the impact of climate change is discounted by half. So he discounts future climate change impacts by the forecast rate of growth of income per head. This has the convenient but essentially arbitrary consequence that we treat, for example, a 10% loss of consumption for a rich generation as equal in value to a 10% loss of the far lower consumption of a poorer generation.[77]

Since the Review assumes that average incomes will rise by 1.3% pa, it discounts by that plus the 0.1% pa estimated risk of extinction. Hence the Review's overall discount rate for the base case is 1.4% pa. In scenarios in which climate change is sufficiently severe to diminish the growth of consumption below 1.3% pa, the rate of discount is also correspondingly

76 Nordhaus *A Question of Balance* p182.

77 In technical terms, this means he assumes the rate of inequity and risk aversion is one. Most estimates of how people actually value this put the rate of risk aversion at a much higher level, with two being somewhat of a consensus value. See Annex to this Chapter.

reduced, as explained in Chapter 6.

Divergence between discount rate and market rate

As mentioned earlier, how we value the wellbeing of ourselves and future generations is essentially subjective. So Stern is entitled to use whatever discount rate reflects his ethical and other values - though not to impose them on the public by a mixture of diktat, moral blackmail and obfuscation, particularly as they conflict with the Treasury guidance on discounting for which he had been responsible as Head of the Government Economic Service. At very least, a public servant like Stern should have spelt out the quantitative implications of his ethical values by including a sensitivity analysis in his published report. By the time a sensitivity analysis was made available, the debate had moved on.

Moreover, using a discount rate that differs from the market rate of return has serious implications which he ignores. Given his claims to superior rationality, Stern should follow through the logical implications of his analysis. He fails to do so.

First and most serious, it means that he does not discount the true cost of investing in global warming – which is the opportunity cost of capital - at the same rate as he discounts the benefits of these investments.[78] If we invest £100 in reducing emissions we hope to create a stream of future benefits from reduced climate change - but we do so at the expense of foregoing the stream of future dividends that £100 could have earned. Both the future benefits and the cost of dividends foregone should be discounted at the same rate. The US government puts the return on capital foregone at 7%; the UK assumes it is 3.5%. To someone who discounts the future at 1.4% pa a stream of dividends of £7 pa is worth £500 - not £100.[79] Likewise, a stream of dividends of £3.5 pa is worth £250. By ignoring this, he potentially understates the cost of his programme by a factor between 2 ½ and 5. He cannot have his cake and eat it. He cannot rationally use his 'ethical' low rate to discount future benefits of cutting emissions but implicitly use a market rate of interest to discount the cost of his programme.

Second, it means he ignores the implications of his preferred discount rate for the level of saving he should be promoting if he "really cares about the future generations". The function of a discount rate is to guide saving and investment decisions. If his discount rate incorporates a rational and ethical imperative, it implies governments should invest in all projects with a social rate of return above 1.4%. Governments should do so via funds like Norway's 'Fund for the Future' and other sovereign funds. That applies not just to projects to reduce the impact of global warming but to anything else

78 Robert Mendelsohn *A Critique of the Stern Report* Regulation Winter 2006/7

79 A stream of dividends of £7 pa discounted at 7% pa is, of course, equal to £100. That is why, when we use the market rate of return to discount the future, there is no difference between discounting the initial cost of capital and the opportunity cost of dividends foregone.

yielding a social return greater than his discount rate. Indeed logically we should increase our investments until the market rate and our discount rate are equal. The rate of return will fall as increasing investment has to go into less profitable opportunities and our discount rate will rise because higher investment generates higher growth, which enters into his discount rate formula. This would require a massive increase in saving and investment to benefit future generations – way beyond the 1-2% of GDP which the Stern Review claims is our ethical duty. The fact that Stern does not even consider this implication of his own analysis undermines his right to condemn others for "not caring much for what happens to future generations".

Ramsey, on whose analysis Stern bases his derivation of his discount rate, recognised that it implied a far higher rate of saving than actually occurs. Following the publication of the Stern report this issue was highlighted in an exchange between two distinguished economists.[80] Das Gupta pointed out that if the social rate of return was 4% pa and people discount the future by 0.1% pa for risk of extinction plus one times the growth of income, as Stern assumes, they could maximise their discounted well-being by saving 97.5% of their income. (This compares with a savings ratio of some 15% of GDP in the UK). This was based on the illustrative assumption that growth comes from returns on capital. DeLong pointed out that if spontaneous improvements of technology and organisation (independent of the amount of saving and investment) generate a growth rate of 3% pa, the optimum savings ratio would be 22.5% - which would still involve increasing UK savings rate by half. In practice, most developed countries' GDP per head seems to grow at less than 2% pa. If between half and all of this is independent of the amount of investment it would imply an optimum savings ratio of between half and three quarters of GDP - way above that actually observed.

Both economists were exploring what would happen if the populace at large followed Stern's reasoning on discounting the future. They assume that behaviour will adapt until the rate of discount equals the rate of return on capital. They tacitly assume that the latter will not change. So the equalisation comes from saving and investing more; this increases growth of consumption which enters into people's discount rate.

Alternatively, the rate of return on capital could be brought down by the weight of additional investment until it equals Stern's prescribed discount rate. Either way, if Stern were consistent he would advocate expanding investment not just on preventing global warming, but also on any other projects yielding more than his discount rate until the rate of return and discount rate are equal.

Stern's Ethics

It is doubtful whether most policy makers realise that, in accepting the

80 Brad DeLong Das Gupta *Applied Utilitarianism and Global Climate Change* 6th Dec 2006.

conclusions of the Stern Review, they are adopting a set of ethical propositions. Without those ethical imperatives it would not be possible to conclude that urgent sacrifices on the scale Stern recommends are necessary to avert future losses. Moreover, these propositions are themselves questionable; they do not conform to how the public behaves in practice, and equally ethical and rational alternatives do exist.

He justifies his low discount rate primarily on the grounds that those who advocate using a higher/market rate "simply do not care much for what happens in the future beyond the next few decades …" - with the implication that a higher rate would lead us to ignore the risk of extinction in the distant future. Most people – including the author of this paper – would care deeply about any threat to the future of humanity. In fact, none of the scenarios the Review shows does result in extinction or even the immiseration of humanity. Even the worst case he displays results in people being several times better off than today. Moreover, as discussed in the Annex to Chapter 6, even if there were a finite risk of global warming wiping out humanity, as long as we attach infinite value to the continuation of the human race, the threat of extinction will dwarf the impact of whatever discount rate we use. So, as long as we put an ethically high value on disastrous outcomes for humanity there is no need for Stern's ethically low rate of discount.

Stern's other ethical imperative is derived from his belief that global warming constitutes "market failure on the greatest scale the world has ever seen". Those who currently benefit from using fossil fuels impose costs on people far into the future. We therefore have an obligation to protect future generations from this damage or to recompense them for it.

The idea of market failure or 'external costs' imposed on others, for example by pollution, is well established.[81] So is the remedy, which is to make the polluter pay a charge sufficient to compensate his victims for the damage they suffer. If the cost of preventing pollution is less than the cost of compensating for the harm it does, the pollution will cease. The difference between global warming and other forms of pollution is that the damage may not materialise until far into the future. That does not alter the principle. To correct for external costs, those who emit carbon dioxide now should pay a tax or charge for each ton emitted sufficient to compensate future victims of global warming. They can do that by paying into a Norwegian style 'Fund for the Future', a sum which, when invested at the market rate of return, will equal the cost of compensating for the future damage when it occurs. The current levy would therefore be equal to future damage caused by emitting an extra ton of carbon discounted at the market rate of interest. If - as Stern maintains - the cost of replacing fossil fuels by other forms of energy is far less than the cost of compensating for the likely damage done by global warming, the economy will be decarbonised, the yield from the levy will dwindle and the need for such a fund will disappear. That is the logic of the 'market failure' approach. Had Stern pursued it, his conclusions would have been broadly in line with the majority of environmental economists.

81 Pigou *Wealth and Welfare* 1912.

However, the Stern Review segues away from his initial market failure approach and adopts a Utilitarian welfare maximising approach. Instead of polluters being required to protect or compensate victims, this involves a single "decision-maker acting on behalf of the community and whose role is to improve, or maximise overall social welfare."[82] This decision maker is assumed to act on our behalf in a perfectly rational and ethical way and therefore discounts future costs using Stern's rate. That assumes we would be willing to sacrifice up to 10% of our current consumption to improve our future consumption – however high that may be - by 10%. And, since we must treat others as ourselves, that means we must be prepared to sacrifice up to a tenth of our consumption to make a future generation, who would otherwise be ten times as rich as us, eleven times as rich.

By the same logic, people living two centuries ago in the early days of industrialisation should have been willing to make sacrifices to ensure that we in the 21st Century, who are rich beyond anything they dreamt of, are richer still.

Most people who would be willing to make sacrifices to 'save humanity' would not want to sacrifice a bean to make future generations even richer. Unfortunately, the basic equation used by the Stern Review assumes that we should treat those richer and poorer than ourselves symmetrically. This makes the algebra simple. However, arguably, an asymmetric approach makes more ethical sense, i.e. we have a positive obligation to compensate those poorer than ourselves for the impact of global warming but no obligation to compensate those richer than ourselves. This is difficult to capture in a convenient mathematical formula. But our ethics should not be driven by algebraic convenience.

There are other ethical systems which do not involve maximising utilities across time and generations. A well established alternative puts an obligation on each generation to pass on to its successors at least as much 'societal capital' as it inherited – above all the accumulated learning coupled with the institutions of democracy and the market which will give our successors the opportunity to advance as we have done, at least materially. A similar rule enunciated by Solow and Hartley says that in using the resources available to us we are morally obliged to ensure that future generations will be able to enjoy equal or higher consumption.

Lord Stern's ethical imperatives may be fairly well buried in his report but at least he makes them explicit. How many politicians or policy makers would be willing to, or have, spelt out to the electorate:

- That most of the benefits of the sacrifices they want voters to make to prevent global warming will accrue to generations living more than two centuries hence, many times richer than us and far more technologically advanced?

82 SR page 31

- That we are asking our electors to sacrifice the interests of today's poor to benefit the future centuries' rich?
- That the threats we face from global warming involve reduced growth in wellbeing, not the extinction of the human race or its permanent immiseration?
- Not to mention that the sacrifices British citizens are invited to make will generate benefits that will accrue largely to people abroad?

ANNEX TO CHAPTER 5: THE RAMSEY EQUATION

As mentioned in the previous chapter, Stern bases his discount rate on the equation originally derived from Frank Ramsey's work "A Mathematical Theory of Saving"[83] in which he sought to establish "how much of its income a nation should save". This is similar to the question of how much a society should be prepared to invest to prevent future damage from climate change.

The basic formula derived from Ramsey's work assumes that there are two possible reasons for discounting future costs or benefits and the discount rate should be the sum of these two elements.

The first reason for discounting is called 'pure time preference' which reflects the lower value we attribute to costs or benefits simply because of the lapse of time between now and when they are expected to occur. The amount by which we discount for each additional year is usually denoted by the Greek letter δ – pronounced 'delta'.

The second reason for discounting costs or benefits is if they accrue to people (including ourselves) with higher incomes than our base level of income. This reflects the fact that an extra dollar is worth less to a rich person than to a poor person. The amount by which we discount for this is the product of two things:

- a factor that reflects the amount by which the utility of additional income declines as income increases. This is called the 'elasticity of marginal utility' and is usually represented by the Greek letter η – pronounced 'eta'. This is multiplied by:

- the amount by which the person's or generation's income is higher (or lower) than the base level. We discount benefits accruing to a generation twice as rich as ourselves by the same amount regardless whether they

83 The Economic Journal, Vol. 38, No. 152 (Dec., 1928), pp. 543-559

are alive tomorrow or a century hence. But because we express discount rates as annual amounts we annualise any increase in income over the time between now and when it occurs. The annualised growth in income is denoted by the letter g.

Thus the total rate of discount – which is usually denoted by the Greek letter, ρ called rho - is given by the equation:

$$\rho=\delta+\eta g$$

Stern follows Ramsey in arguing that there is no rationale for a positive rate of pure time preference for as long as one is confident that the human race will continue to exist. He argues that it involves valuing costs and benefits accruing to different generations on the basis of their date of birth. However, if humanity is expected to survive indefinitely then the net present value of even a tiny loss of income to all future generations undiscounted for ever would be infinite, justifying huge sacrifices from the present generation. To avoid this ludicrous result, Stern gives delta the fairly arbitrary value of 0.1% pa, representing the possibility of extinction. (Unlike Stern, Ramsey avoided the problem of projecting a society's wellbeing to infinity by assuming it would approach the satiation of its wants – a state he called 'bliss' when further saving would be pointless – in a finite though unknown time. It was this elegant solution that won him the plaudits of Keynes and others.)

The variable eta is the hardest to grasp. The Stern Review gives it a value of 1. This has the convenient consequence that a marginal cost or benefit accruing to a generation 10% richer than us is discounted by 10%.

Eta is conventionally seen as performing three functions simultaneously: consumption-smoothing over time, aversion to inequality and aversion to risk. It is not immediately obvious that a single variable can, or should, stand for three things.[84] Whether it should do so or not, the reason it can do so is that in each case we assume that the marginal utility of a cost or benefit declines as the income of the recipient rises. The higher the value we attribute to eta, the less value we put on costs and benefits accruing to ourselves when we are richer, or to others who are richer than us, or to those outcomes of an uncertain world which result in higher incomes. In respect of consumption smoothing: the higher eta, the less we will be willing to save and invest now if we expect to be richer in future. In respect of inequality aversion: the higher eta, the more people will be willing to redistribute to help top up the incomes of those poorer than themselves but the less willing they will be to help make richer future generations even richer. In respect of risk aversion: the higher eta the more averse people will be to risk since they will weigh more heavily negative outcomes which leave them worse off than positive outcomes that make them richer.

There is some empirical evidence of how people do save, run down their

84 Saelen, Haakon, Giles D. Atkinson, Simon Dietz, Jennifer Helgeson, and Cameron J. Hepburn. *Risk, Inequality and Time in the Welfare Economics of Climate Change: Is the Workhorse Model Underspecified?* Department of Economics, Oxford University Discussion Paper 400, 2008.

savings or borrow to smooth their own consumption, how much they are willing to redistribute to reduce inequalities and how averse they are to risk. The low value of eta, 1, chosen by the Stern Review would imply a far higher level of savings than is observed – see below. On the other hand, a high value of eta would imply a greater willingness to redistribute income to the poor than appears to be the case from foreign aid programmes – though that may show governments are more averse to domestic inequality than to international inequalities. Stern can scarcely use the reluctance of people to transfer income to poor people now to justify his ethical insistence that today's generation must make sacrifices to help richer future generations.

Since publishing the Review, Stern has changed his view on the appropriate value for eta. He says he would now use a value of 2.[85] This would mean his basic discount rate would be 2.7% pa, dramatically reducing his headline estimates of the cost of global warming. Instead of being equivalent to a loss of 5% of GDP 'now and forever', his base case loss would be about 1.5% and his 'high climate' case loss would be reduced from 14.4% of GDP to about 5% 'now and forever'.

However, for extreme catastrophes which would result in consumption falling below current levels a higher value of eta would result in higher negative discount rates. This could offset the low probability attached to such events and therefore contribute towards more significant expected losses.

None of the results depicted in the Stern Review showed consumption falling. But Stern has moved a long way from his original Review. Instead of relying on estimates of losses arising from most likely scenarios to justify radical action, he falls back on appeals to unspecified catastrophes. A high eta helps give that position some intellectual backing.

85 "with the benefit of hindsight, my inclination would be ... a higher eta ... there is a case for raising eta, although it remains true that many would see the implications of eta = 2 for intragenerational distribution as very egalitarian." Stern *The Economics of Climate Change*, Ely Lecture, American Economic Review: Papers & Proceedings 2008.

CHAPTER 6 - TREATMENT OF UNCERTAINTY AND RISKS

"We all agree that pessimism is a mark of superior intellect." J K Galbraith[86]

"There is nothing more irresponsible than pessimism." Karl Popper

Uncertainty

There is an additional reason for discounting the future which has not been mentioned so far. That is to account for uncertainty.

The analysis discussed in the previous chapter, from which Stern derives his discount rate, tacitly assumes that we have perfect foresight of the future. Unfortunately we do not – the further ahead we look the less certain our forecasts must be.

In the business world it is common to use a higher discount rate the greater the uncertainty about the future. Stern argues for the reverse.

The Review tackles uncertainty by weighting all possible outcomes by their probability and then discounting them. But it uses a lower discount rate the less well off the outcome leaves us. The effect is to reduce the average discount rate the wider the range of outcomes.

The Review assumes that uncertainty consists of a wider dispersion of possible outcomes the further we look into the future. The greater the dispersion, the lower the weighted average discount rate. Hence the declining discount rate over time.

This approach would be valid if we could assume, as Stern does, that the future will be like what we already know - except for ever wider uncertainty about the value of a number of key variables. The Stern Review effectively assumes that we know with certainty the structure of the future but are only uncertain about some of its dimensions – like climate sensitivity (how much temperature rises for a given increase in CO2 concentrations) or how much damage a given temperature increase will cause.

However, businesses look at the future rather differently, which is why they use a higher discount rate to account for greater uncertainty. They do so for two reasons:

First, the less well we can foresee the future, the less we can meaningfully say about it. Using a higher discount rate shortens the time span over which our guesstimates of the future have any meaningful present value. We cannot assume, as Stern effectively does, that for centuries ahead the world will

86 The Observer, London, 3rd April 1977

be like what we already know except for ever wider uncertainty about the magnitude of a few key variables. The chances are it will be totally different in utterly unforeseeable ways. This may render the concerns which currently preoccupy us, and which we are trying to project, wholly irrelevant. We can assume that the laws of physics and (perhaps) economics will not change. But the climate, our environment, our economy and our society will be the consequence of thousands of different physical and human processes interacting in a potentially infinite number of ways we only partly understand. There is no known and certain structure that defines the outcome but for the dimension of a few variables.

Could anyone in 1900 have foreseen two World Wars, the Great Depression, the rise and fall of fascism and communism, the end of colonialism, the invention of jet planes, TV, the internet, mobile phones; the quadrupling of the world's population at the same time as living standards increased many-fold, etc? Concerns in 1900 about the imminent exhaustion of coal supplies, the exponential growth of horse manure in cities, the immiseration of the masses etc proved irrelevant well before the century was out. We cannot even forecast what the global surface temperature will be absent carbon emissions: many scientists assume another ice-age is on the way within a few millennia.

Secondly, businesses also use a higher discount rate to deal with uncertainty because they assume that, for any investment project, unforeseeable events are more likely to make it less profitable than to boost its profitability. This is not just aversion to negative risk, nor a belief in Sod's Law; it is because the very needs which make the investment appear profitable are likely to attract new competitors, stimulate human ingenuity and call forth as yet unforeseeable alternatives. At the same time, costs are more likely to be higher than anticipated because of unforeseeable technical or supply problems. In a complex system or project there are always more unforeseeable things that are likely to go wrong than right.

To some extent the same asymmetry may hold true for investments to mitigate global warming. Given human ingenuity, the very existence of the problem may elicit as yet unforeseen and unforeseeable alternative ways of tackling it, whereas the costs of the investments we plan are more likely to be underestimated than the reverse.

The effect of using a higher discount rate to reflect this kind of uncertainty accords with common sense. It ascribes less weight to our projections of the consequences of our actions (and inactions) the more distant and uncertain they are. It implies a degree of humility about our ability to know the distant future. By contrast, the assumption that we can predict the consequences of our actions centuries, indeed millennia, ahead – our only uncertainty being the precise magnitude of those consequences - involves the most breathtaking hubris.

Risks

As well as arguing that uncertainty justifies using a low discount rate, the Stern Review makes a number of assumptions about specific risks which also contribute to his high estimates of the impact of global warming.

- **Range of values for climate sensitivity**

The key variable in forecasting future temperatures is the 'climate sensitivity'. This is defined as the amount by which the global average surface temperature increases if the concentration of greenhouse gases doubles. Stern was working when the only published IPCC estimates were those produced in the Third Assessment Report in 2001. However, he was aware of, and broadly anticipated, the conclusions of the IPCC's Fourth Assessment Report, which came out the year after his Review. The Fourth Assessment Report

> "concludes that the … 'equilibrium climate sensitivity', is likely to lie in the range 2° C to 4.5° C, with a most likely value of about 3° C".[87]

Most studies cited by the IPCC of the impact of man-made global warming assume the climate sensitivity will fall within that 2-4.5° C range. They generally assign probabilities peaking at the most likely value of 3° C and declining towards zero for values beyond the ends of the range. However, the IPCC added that

> "For fundamental physical reasons as well as data limitations, values substantially higher than 4.5°C still cannot be excluded, but agreement with observations and proxy data is generally worse for those high values than for values in the 2°C to 4.5°C range."

Anticipating the first part of this statement and ignoring the second, Stern allowed for higher sensitivities way outside this range - albeit with decreasing likelihood. Since under his Business as Usual scenario the level of greenhouse gases will more than double by 2100, he allows for temperature increases as high as 10° C by then. An even wider range of catastrophically high temperatures is postulated in a sophisticated defence of Stern's conclusions by Martin Weitzman. This is considered in depth in the Annex to this Chapter – Is Stern Right for the Wrong Reasons?

- **Catastrophic climate impacts**

Even in its base case, the Review allows for what it labels 'catastrophic' impacts at higher temperatures. It assumes that when the temperature passes a threshold (which itself is an uncertain variable averaging 5°C above pre-industrial levels), the chance of a catastrophe increases by 10% for every additional degree of warming. The scale of the catastrophe is a random amount which reduces GDP by between 5 and 20%.

87 Although the IPCC Report came out the year after Stern published his review, Stern broadly anticipated the 'likely' range of sensitivities.

Although the impact of catastrophes is incorporated simply by the formula just indicated, the Review refers to three phenomena as potential catastrophes:

1. **Release of methane from hydrate stores** - Huge quantities of methane may be stored under pressure and at low temperatures deep in the ocean in the form of clathrates. If ocean warming penetrated deep enough to release some of this methane – which, ton for ton, is 25 times more potent than CO2 as a greenhouse gas – it could amplify global warming considerably. This is additional to the possible release of methane stored in wetlands and permafrost which is accounted for in Stern's High Climate scenario. As Stern acknowledges:

   > "There is considerable uncertainty whether these deposits will be affected by climate change at all".

   Indeed, climate models assume the greenhouse effect first heats waters near the surface – if the heat were to spread rapidly throughout the depths of the oceans the temperature rise would be slow. If there were a risk of destabilising clathrates, it would presumably have occurred in previous episodes of geological warming. But a recent study[88] of carbon isotopes in methane stored in Arctic ice cores has shown that even the large increase in methane during the abrupt warming of 10 +/-4°C that occurred nearly 12,000 years ago came from wetlands not from oceanic clathrates. The past is an imperfect guide to the future, but the chance of a release of methane from clathrates seems to be small. However, there could be other sources of methane releases, perhaps large, perhaps abrupt.

2. **Weakening or reversal of the Gulf Stream** – known as the Atlantic Thermohaline or Meridional Overturning Circulation. At present the Gulf Stream moves warm water from the tropics to the North Atlantic, contributing to the comparatively benign climate of Western Europe. It has been suggested that this circulation could be slowed or reversed by fresh water released by melting of the Greenland ice sheet. The somewhat paradoxical suggestion is that global warming could thereby plunge Europe into a deep freeze. Even the Stern Review admits that:

   > "No complex climate models currently predict a complete collapse. Instead, these models point towards a weakening of up to half by the end of this century … but this would only offset a portion of the regional warming due to greenhouse gases."

   The IPCC reached the same conclusion. It is not clear why this should be classified as a catastrophe. In the more extreme scenarios, a reversal of the Gulf Stream would return Britain to its current climate – disappointing,

88 Petrenko, Vasilii V.; Andrew M. Smith, Edward J. Brook, Dave Lowe, Katja Riedel, Gordon Brailsford, Quan Hua, Hinrich Schaefer, Niels Reeh, Ray F. Weiss, David Etheridge, and Jeffrey P. Severinghaus. *14CH4 Measurements in Greenland Ice: Investigating Last Glacial Termination CH4 Sources*. Science 324: 506-508

surely, but no disaster.[89]

3. **Melting of the Greenland ice sheet or collapse of the West Antarctic ice sheet[90]** - The Review says

> "If the Greenland and West Antarctic ice sheets began to melt irreversibly, the world would be committed to substantial increases in sea level in the range 5-12 metres over a time scale of centuries to millennia."

The IPCC confirms that this process would take millennia (not centuries):

> "If a negative surface mass balance were sustained for millennia, that would lead to virtually complete elimination of the Greenland ice cap."[91]

Normally a catastrophe is seen as an abrupt and unpredictable event. A process requiring millennia scarcely befits that description. Moreover, previous warmings of a comparable scale, like the Eemian some 125,000-130,000 years ago, did not render Greenland ice free even over thousands of years. Likewise, ice cores from Antarctica show it has remained icebound for at least 750,000 years despite considerable variations in global average temperatures over that period.

Even the maximum sea-level rise estimated in the Stern Review is far from unprecedented. Over the last 18,000 years since the last ice age, the sea level has risen by some 120 metres, averaging two-thirds of a metre per century. In recent centuries the rate of rise has been slower and the increase forecast by the IPCC for Stern's chosen scenario this century is between 23 cms and 51cms. Tokyo has experienced a relative sea level rise of 5 metres in the 20th century (primarily because of subsidence) and thrived nonetheless.

The world is perfectly capable of adapting to the sort of increase forecast by the IPCC without the catastrophic loss of 5-20% of GDP which Stern's model assumes.[92]

If any country should worry, it is the Netherlands. Yet as a senior Dutch scientist put it:

> "In the past century the sea level has risen twenty centimetres. There is no evidence for accelerated sea-level rise. It is my opinion that there

89 *Estimation of the economic impact of temperature changes induced by a shutdown of the thermohaline circulation: an application of FUND* P. Michael Link and Richard S. J. Tol "Climatic Change 16th Jan 2010

90 *Global estimates of the impact of a collapse of the West Antarctic ice sheet: an application of FUND* Nicholls, Richard S. J. Tol and Athanasios T. Vafeidis Climatic Change 28 March 2008

91 Significant latent heat is required to transform ice to water at its melting point. Given the net heat balance entering the earth system as a result of the greenhouse effect, which is a key element in any climate model, it is comparatively easy to calculate that millennia will be required to melt the ice caps which are several kilometres thick, even once the ice reaches melting point.

92 *Sea-level rise and its possible impacts given a 'beyond 4°C world' in the twenty-first century*. Nicholls, Marinova, Lowe, Vellinga, Gusmão, Hinkel and Tol Phil Trans R Soc A January 13, 2011

is no need for drastic measures. Fortunately, the time rate of climate change is slow compared to the life span of the defence structures along our coast. There is enough time for adaptation."[93]

Although the Review is opaque on the issue, it appears that the formula for catastrophic damages incorporated in the Integrated Assessment Model assumes that the damage they wreak occurs with at most a brief lag after the temperature reaches a given level. It effectively brings forward the damage likely from melting ice sheets by centuries if not millennia.

So of the three 'catastrophes' cited in the review, one is potentially beneficial, one has not occurred during previous warm periods and the third will take thousands of years to materialise, giving us plenty of time to adapt to, or prevent, it.

Nonetheless, the 'catastrophe' element in the Review contributes some 2.9% per annum to its estimate of the reduction in GDP from climate change. This is included in Stern's headline conclusion that if no action is taken to limit emissions the world stands to lose 5% of GDP now and forever.

- **High Climate Scenario**

The Review also introduced a 'High Climate' scenario which included estimates of two amplifying feedbacks. These are that higher temperatures will, first, weaken the ability of plants and the soil to absorb carbon dioxide and, second, release methane from wetlands and permafrost. These 'carbon feedbacks' had not been included in the IPCC's 2001 projections but are incorporated in the 2007 assessment. However, in its 2007 report, the IPCC noted that:

"Recent measurements show that CH4 [methane] growth rates have declined and were negative for several years in the early 21st century … The observed rate of increase … is considerably less than assumed in all the IPCC scenarios …"

The Review estimated that, on its chosen emissions scenario, these feedbacks add 0.4°C to temperatures by the end of this century and increase the likely range within which the temperature is 90% likely to fall to between 2.6°C and 6.5°C. However, that left a 10% chance of increases outside that range. Stern herefore includes a small likelihood of increases of 10°C and even more in his simulations. Because damage is assumed to increase disproportionately with temperature, these extreme values, even when assigned low probabilities, contribute disproportionately to the total estimated damage. Stern's belatedly published sensitivity analysis showed that the 'High Climate' scenario had an effect equivalent to reducing future world consumption by 3.5% pa 'now and always'.[94]

93 Wilco Hazeleger, senior scientist in the global climate research group at the Royal Netherlands Meteorological Institute. NRC/Handelsblad 11/12/2008.

94 Technical Annex to the Postscript to Stern Review table PA.2

• **Monte Carlo modelling**

The Review runs the PAGE model 10,000 times using randomly chosen different values of over 30 different variables and then averages the outcomes. The most important of these variables is that which determines how rapidly the damage caused by climate change increases with temperature.

The Review sets the PAGE model to calculate damages, starting with the assumption that they rise at a minimum directly in line with temperature and at a maximum in line with the temperature cubed – or temperature raised by any power between 1 and 3, with 1.3 as the most common value and the average at 1.8.

The effect of this and other variations used in these Monte Carlo simulations is to increase the estimate of damages by 7.6% pa of GDP compared with just doing a single run with one central estimate for each variable.[95]

An indication of the importance of the relationship between damage and temperature is given by allowing all other variables to take a range of values but always setting damages as proportional to the cube of the temperature. This would have increased the total estimate for damages by the equivalent of 11.4% of GDP.[96]

Monte Carlo modelling is a perfectly respectable way of calculating the most likely outcome of a process where several variables could take a range of values of known probability. The danger is that it can emphasize results that are based on extrapolating functions far outside their range of empirical validity. This danger is more pronounced in reduced-form models, such as the one used by the Stern Review.

Overall impact of Stern's treatment of risk and uncertainty

It is important to recognise that even Stern's basic scenario, which produced losses of 5% of GDP "now and forever", incorporates the probability of catastrophes which account for a majority of those anticipated losses. He has to invoke a "High Climate Scenario" to raise expected losses by a further 3.5% of GDP. Moreover, Monte Carlo modelling allows for outcomes way beyond any empirical experience and the worst outcomes are discounted at an effective rate below even his standard low discount rate of 1.4% pa. Even so, future generations are expected to be substantially better off than the present on more than 90% of the potential outcomes (see Table 1 in Chapter 2).

The Review's estimates of damages are substantially higher than those of most environmental economists. Yet at the same time, estimates of

95 *Debating Climate Economics: The Stern Review vs. Its Critics* Report to Friends of the Earth-UK Frank Ackerman

96 Ibid

future GDP increases foregone have not proved as alarming as Stern may have hoped. Consequently, for lay audiences, Stern increasingly relies on shroud-waving visions of mass migration and conflict[97] which will supposedly be induced by global warming even though these phenomena are not included in his cost estimates.[98] If they are indeed a real threat rather than the best rhetorical device to mobilise support, then, it is, to say the least, bizarre to omit them from his calculations.

For academic audiences he relies increasingly on a sophisticated version of the 'precautionary principle' enunciated by the distinguished economist, Martin Weitzman. Weitzman is highly critical of Stern's economics, not least his choice of discount rate. But he argues that Stern may be "right for the wrong reasons". In a nutshell, Weitzman argues that: if there is a finite probability of an infinitely bad outcome (like the extinction of the human race), then the impact dwarfs almost any discount rate, so it is worth devoting all our resources (short of risking our survival) to prevent it. More controversially, he argues that this is the case with global warming – even though none of Stern's scenarios involves the risk of extinction, or anything like it. Weitzman's thesis is discussed in more detail in the Annex to this Chapter entitled "Is Stern Right for the Wrong Reasons?"

Annex to CHAPTER 6 - Is Stern "Right For The Wrong Reasons"?

"Physics is the only real science. The rest are just stamp collecting." Ernest Rutherford

"As far as the laws of maths refer to reality, they are not certain and as far as they are certain, they do not refer to reality." Albert Einstein

As Stern's economics have come in for strong criticism, his defenders have increasingly invoked various versions of the 'precautionary principle' to justify his conclusions. Typically these state that if there is even a small chance of a catastrophe that threatens human life on this planet, it would be worth making any conceivable sacrifice (short of steps which would also risk our survival) to prevent it.

The Stern Review includes risk of catastrophes as discussed in Chapter 6. But when weighted by probability, even when discounted at Stern's low rate,

97 Lionel Robbins Memorial Lectures, Nicholas Stern, LSE, February 2012.

98 Yale Symposium on the Stern Review February 2007 p24.

they do not result in numbers which dwarf potential costs of prevention.

However, the distinguished Harvard economist Martin Weitzman has applied a more sophisticated version of the 'precautionary principle'- which he calls his 'Dismal Theorem' - to global warming with more dramatic conclusions. Stern's defenders increasingly refer to this to justify their conclusions so it is important to examine it here.

Weitzman is highly critical of the Stern Review, dismisses Stern's "economic modelling of climate change impacts, which deservedly has drawn strong criticism from economists"[99] and rejects Stern's ultra-low discount rate, preferring to use a market rate of 6% pa, which he also justifies from first principles. Yet he draws back from rejecting Stern's conclusion that a crash programme to prevent global warming would be justified and concludes that Stern may nonetheless be "right for the wrong reasons".[100]

Weitzman's 'Dismal theorem' in essence states: if there is a finite probability of an infinitely bad outcome (like the extinction of the human race), then the impact dwarfs almost any discount rate so it is worth devoting all our resources (short of risking our survival) to prevent it. He argues that this is the case with global warming.

His argument rests on a series of assumptions which it is important to make explicit.

1) Weitzman's approach involves abandoning claims that the science of global warming is settled, certain and derives from known physical laws. Weitzman's most crucial hidden assumption is that physics cannot tell us, even to the nearest order of magnitude, the value of Climate Sensitivity. This is the key parameter on which all projections of global warming rest.[101] (It is defined as the amount by which the surface temperature will ultimately rise if the concentration of CO2 doubles).

Weitzman assumes that we must estimate Climate Sensitivity empirically by measuring the relationship between changes in concentration of greenhouse gases or radiative forcings and surface temperature, ocean heat content etc. Such estimates are inevitably uncertain because of natural variance, poor model specification and measurement errors. Moreover, that variance is itself uncertain. Weitzman argues that the probability of extreme

99 *A Review of the Stern Review on the Economics of Climate Change* Martin Weitzman. Journal of Economic literature Sept 2007. Weitzman has returned to this issue a number of times, notably in *On Modelling and Interpreting the Economics of Catastrophic Climate Change*, Review of Economics and Statistics 2009 and *Fat-Tailed Uncertainty in the Economics of Catastrophic Climate Change* 23rd February 2011, REEP Symposium on Fat Tails.

100 Weitzman 2007.

101 Climate Sensitivity is the sum of a number of factors and interactive processes. The basic greenhouse effect – the impact of increasing greenhouse gas concentrations on temperature – can be derived from physical laws. On its own it would suggest a Climate Sensitivity of around 1°C for doubling CO2. However, a rise in temperature will induce feedbacks – some positive, some negative - which combine to produce the total Climate Sensitivity. Some, like the increase in water vapour, can in principle be quantified on the basis of physical laws. Others, like the reduction in albedo – the amount of light reflected by ice – as polar ice melts can be calculated to a reasonable approximation. But the impact of other factors, like clouds, is much less certain – even as to whether it is, on balance, positive or negative.

values should therefore be presumed to be 'fat-tailed' i.e. the likelihood of increasingly high values declines less rapidly than the damage they may inflict; and he believes that we cannot put any upper limit on the Climate Sensitivity.

In contrast to Weitzman's approach, most of those who argue that man-made global warming is a serious threat, including Stern, assert that the science of global warming is known and certain because it is based on clear physical laws - from which the value of the Climate Sensitivity could be determined pretty precisely. Stern says:

> "The key conclusion, that the build-up of greenhouse gases in the atmosphere will lead to several degrees of warming, rests on the laws of physics and chemistry."

Likewise the IPCC says:

> "Climate models are based on well-established physical principles".

Modellers deny that their models are based on 'curve fitting' or 'tuning'. Thus John Hirst, CEO of the Met Office, explaining his refusal to adjust the Climate Sensitivity ('net positive feedback') in the light of the recent pause in global warming, wrote:

> "We stress that this net positive feedback is not imposed upon the models [by tuning them to fit observations] but is a consequence of the physical processes and interactions that have been represented in the models."[102]

They are at pains to reject allegations of curve fitting since, where there are several unknown parameters, it is possible to select values for those parameters which make almost any curve or model roughly conform to observed data. The prominent mathematician, John von Neumann, said:

> "With four parameters I can [make a curve] fit an elephant and with five I can make him wiggle his trunk."

The laws of physics are certain and, at this level, deterministic. If all the feedbacks which combine to determine the Climate Sensitivity were known and could be derived from those laws that would rule out the unlimited uncertainty as to its value on which Martin Weitzman's thesis depends. So the Dismal Theorem would not apply to global warming.

On the other hand, Weitzman would presumably argue that, although the laws of physics are certain, the interaction of physical processes within the climate system is immensely complex and this precludes us from deducing from physics any value for the Climate Sensitivity[103], hence his reliance on

102 Letter from John Hirst to Hilary Benn published in reply to a Parliamentary Question by Peter Lilley on 18th June 2009.

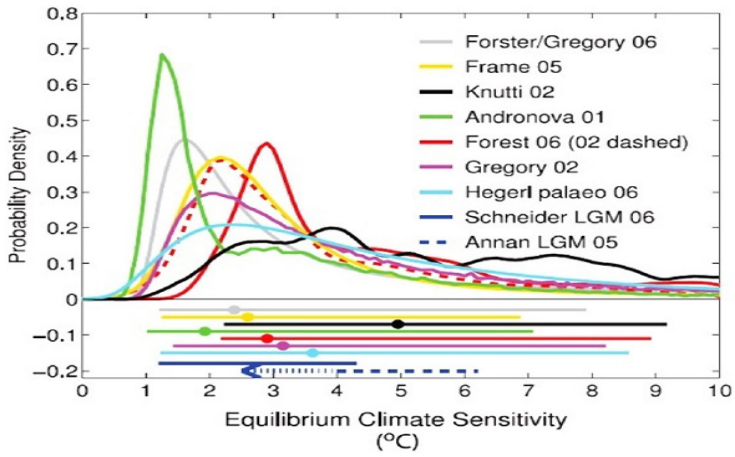
103 In fact many climate processes, not least those to do with clouds, are uncertain and therefore do introduce an unquantifiable element of uncertainty into the Climate Sensitivity implicit in climate models. The physics of each of the processes which go into cloud formation and behaviour are well known – evaporation, adiabatic cooling, condensation, latent heat, radiative reflection and absorption etc. But we cannot calculate the net quantitative impact of how these

empirical estimates with their inherent uncertainty.

In short: either we accept Stern's claims that the science is clear and settled, in which case Weitzman's thesis cannot be invoked to rescue Stern's economic conclusions; or we can rescue Stern's conclusion that the costs of decarbonising the world's economy are worthwhile. But this means saying the science is so uncertain that the Climate Sensitivity could conceivably take values way beyond anything suggested by known physical processes and feedbacks.

2) Weitzman assumes that we will not know if Climate Sensitivity is extremely high until too late to do anything about it. Martin Weitzman draws on 22 studies assembled by the IPCC which have calculated Probability Distribution Functions (PDFs) for their estimates of Climate Sensitivity.

Figure 3: PDFs of the Climate Sensitivity shown in the IPCC report



Comparison between the different estimates of the PDF (or relative likelihood) for ECS (°C). All PDFs/likelihoods have been scaled to integratre to unity between 0°C and 10°C ECS. The bars show the respective 5 to 95% ranges, dots the median estimate. The PDFs/likelihoods based on instrumental data are from Andronova and Schlesinger (2001), Forest et al. (2002; dashed line, considering anthropogenic forcings only), Forest et al. (2006: solid, anthropogenic and natural forcings), Gregory et al. (2002a), Knutti et al. (2002), Frame et al. (2005), and Forster and Gregory (2006), transformed to a uniform prior distribution in ECS using the method after Frame et al. (2005). Hegert et al. (2006a) is based on multiple palaeoclimatic reconstructions of NH mean temperatures over the last 700 years. Also shown are the 5 to 95% approximate ranges for two estimates from the LGM (dashed, Annan et al. 2005; solid, Schneider von Deimling et al., 2006) which are based on models with different with different structural properties. Note the ranges extending beyond the published range in Annan et al. (2005), and beyond that sampled by the climate model used there, are indicated by dots and an arrow, since Annan et al. only provide an upper limit. For details of the likelihood estimates, see Table 9.3. After Hegert et al. (2006a).

Source: IPCC

processes combine – there is even some doubt as to whether it is +ve or –ve.

PDFs are normally calculated for random 'stochastic' variables and reflect the frequency with which each value occurs. Because the discussion is in terms of probabilities it is easy to forget that Climate Sensitivity is not a random variable. It is a constant or, rather, it is determined by a set of constant relationships. It does not take one value this year and another next year.[104] Some of the processes may take time to reach equilibrium, so the Effective Climate Sensitivity in the time scale of most studies may be different, probably lower, than the Equilibrium Climate Sensitivity. And additional feedbacks may come into play above a certain temperature threshold. None of that alters the fact that, over the time scale that each of the IPCC's studies tried to measure it, the Climate Sensitivity can be taken as constant.

If the true value of Climate Sensitivity is very high, it will not just be high in the future, it must be high now and it will have been high in the past.

Greenhouse gas concentrations are over half way to doubling since the industrial revolution. If the true value of Climate Sensitivity is, as Weitzman postulates, over 10°C for a doubling of CO2, we might have expected at least a 5°C rise in the world's temperature by now. In fact, it has risen by barely 0.8°C over the last couple of centuries. That is only compatible with a Climate Sensitivity over 10°C if man-made warming has been obscured or offset. It is theoretically possible that a high value could have been masked by a very skewed pattern of natural variations (likely to revert to the mean); if the heat has dissipated into the deep ocean (which should be revealed by more advanced ocean monitoring); or if the greenhouse effect has been offset by a matching increase in aerosols. Aerosols are mostly minute droplets of sulphates derived from burning hydrocarbons. They reflect back some of the sun's radiation before it reaches the earth's surface. The aerosol explanation is the favourite and is built into most climate models. However, aerosols are emitted predominantly in the northern hemisphere and, unlike CO2, do not remain in the atmosphere long enough to mix across the equator. So the northern hemisphere should be cooler, yet has in fact warmed markedly more than the southern hemisphere. In any case, aerosols are short lived in the atmosphere and new emissions are expected to decline as China and other fast developing countries fit scrubbers to their power stations to remove SO2 emissions. Even if the quantity of aerosols emitted annually simply stabilised, they would no longer offset the effect of rising concentrations of CO2, which would therefore reveal their full warming effect.

If the true value of the Climate Sensitivity is very high, that should manifest itself in rapid temperature increases relatively soon. This would give the world an early warning that strong measures are indeed needed in time to prevent further dramatic warming – a possibility Weitzman rules out.

104 Climate Sensitivity may conceivably have had a somewhat different value in other geological epochs. For example, when the continents were in different places or covered with forest the earth may have reflected a different proportion of the sun's rays, thereby affecting the Climate Sensitivity. But its value is determined by physical processes which do not vary randomly.

3) Weitzman assumes that there is a realistic threat, albeit small, of the virtual extermination of the human race as a result of global warming. The worst that even Stern assumes in his most pessimistic scenario is that, if we take no steps to restrain greenhouse gas emissions, global warming will diminish the value of consumption from 2200 onwards by around a third of what it would otherwise have been. That would still mean that average consumption per head would be some 7 or 8 times today's level[105] – scarcely the equivalent of annihilation.

The possibility that higher temperatures could wipe out humankind is necessary for his maths to work since annihilation would be an infinitely bad outcome which, given even the smallest probability of it occurring, would outweigh even the heaviest discounting. He believes that there is a finite possibility of very high temperatures even if the world follows the gradual ramp up route which most economists – in contrast to Stern - recommend to stabilise greenhouse gas concentrations. And he asserts that:

> "because these hypothetical temperature changes would be geologically instantaneous, they would effectively destroy planet earth as we know it."[106]

The "as we know it" is a handy qualification – not quite the same thing as destroying humanity itself.

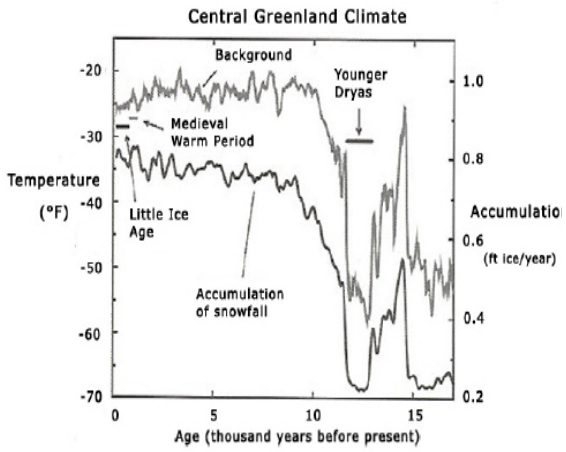
In fact, the world does seem to have seen, during humankind's sojourn on earth, very sharp temperature increases of the same order of magnitude as Weitzman fears. During the 'Younger Dryas' some 12,000 years ago, the earth seems to have cooled dramatically and then warmed rapidly - by as much as 10°C in fifty years, one study shows.[107] Humankind survived despite having far fewer technological resources to help them adapt, just as stone age man survived the ice ages which must have "effectively destroyed the planet" as they knew it.

105 See Table 1 above.

106 *On modelling and interpreting the economics of catastrophic climate change* Martin Weitzman. The Review of Economics and Statistics Feb 2009 p5.

107 Kobashia, Takuro; et al. (2008). "4 ± 1.5 °C abrupt warming 11,270 years ago identified from trapped air in Greenland ice". *Earth and Planetary Science Letters* 268 (3–4): 397–407

Figure 4: The history of temperature and the rate at which snow accumulated in central Greenland over the last 17,000 years. The prominent Younger Dryas cold event, and the warmings and coolings before it, dwarf the climate changes that helped chase the Vikings around.



Source: Richard B. Alley, The Two Mile Time Machine: Ice cores, abrupt climate change, and our future (Oxford: Princeton University Press, 2000)

High temperatures would certainly change the world beyond recognition, as may many other things over the next couple of centuries. Most people would probably not want to risk provoking such changes if they were seriously likely, rather than just remotely conceivable. In a more recent version of his thesis[108], Weitzman prays in aid a study[109] which suggests that a double digit temperature increase would mean half the world's population would be liable to hyperthermia unless there is "much wider adoption of air conditioning" which it assumes "would surely remain unaffordable for billions in the third world". This reveals very explicitly the 'growth inconsistency' in such alarmist forecasts: they simultaneously assume sustained economic growth based on rising energy use and that the world remains poor. Weitzman himself points out:

> "It must be said clearly that very high atmospheric temperature changes like 10°C can take several centuries to attain".

So although such temperatures and reliance on air conditioning are a ghastly prospect, they are not equivalent to annihilation. And who knows what technologies, and how affordable, will be available to make life nonetheless agreeable in 2200, should temperatures rise greatly?

108 *Fat-Tailed Uncertainty in the Economics of Catastrophic Climate Change* REEP Symposium on Fat Tails Martin Weitzman February 2011

109 *An adaptability limit to climate change due to heat stress* Sherwood and Huber PNAS 2010. The realism of this study has been heavily criticised by Roger Pielke Snr and others.

Lindzen points out that high climate sensitivity requires large feedbacks, which would have made the climate extremely unstable, and likely to have led to runaway climate change at some point in the past – which fortunately has not been the case.

> "The feedback factor[110] is almost certainly not a true constant[111] … If climate sensitivity is currently large it is unlikely that over the 4.5 billion years of the earth's history [the feedback factor] would not have exceeded one, and then we would not be here discussing this."[112]

4) Weitzman ignores countervailing risks. Although Weitzman assumes we are ignorant of the key parameter of climate change and the physical processes that determine our climate, he implicitly assumes we do know there are no countervailing risks. Such risks might include reliance on nuclear energy resulting in nuclear proliferation and war, or the risk of the earth entering another ice age. Most geologists take it as given that the earth is currently well into an 'interglacial'. Weitzman puts no weight on the possibility that CO2 emissions may by serendipity protect us from global cooling – a far worse threat than warming.

5) Weitzman assumes that global warming is unique in having a fat tail of risks of devastating consequences. Others have pointed out[113] that Weitzman's logic could be applied to many other threats which could allegedly result in the extermination of humankind and of which we cannot say the risk is zero: nuclear proliferation, asteroid collision, genetic engineering, 'strangelets'[114], nanotechnology, intelligent robots. It would be easy, given Weitzman's analysis, to justify pre-emptive military action (starting, no doubt, with Iran) if there is even a small risk of nuclear annihilation should more countries obtain such weapons. Likewise, we should be devoting huge resources to building nuclear devices to divert the course of oncoming asteroids and forego the advantages of genetic technology, nanotechnology and particle physics. Weitzman responds that the risks of man-made global warming are greater than these other risks. That is mere assertion. But the logic of his analysis is that we must be prepared to make huge sacrifices to cope with any and every uncertain but non-zero risk of annihilation. All these precautionary programmes would be competing for the same huge share of the world's

110 The rise in temperature $\Delta T = \Delta T0/(1-f)$, where $\Delta T0$ is the zero feedback response to a doubling of CO2. It is about 1°C. So as the feedback factor f approaches 1, the temperature increases exponentially.

111 This is comptatible with the statement above that "over the time scale that each of the IPCC's studies tried to measure it, the Climate Sensitivity can be taken as a constant" but it "may conceivably have had a somewhat different value in other geological epochs". Over the billion years to which Lindzen refers a variety of different feedbacks would have come into play.

112 Climate Models and the Evidence. Richard Lindzen, Seminar in House of Commons 22nd Feb 2012

113 *An Analysis of the Dismal Theorem* by William Nordhaus, Cowles Discussion Paper 1686 Jan 2009. Yale University. See also *The Economics of Tail Events with an Application to Climate Change* William Nordhaus, Review of Environmental Economics and Policy, Summer 2011.

114 It has been suggested that particle accelerators like CERN could create mini black holes into which our universe would be sucked.

resources.

Calculation of probabilities from empirical studies

Martin Weitzman relies heavily on empirical studies to derive probabilities for Climate Sensitivity having extreme values. It is important to understand what these studies measure and how they are calculated.

Above all, it should be remembered that Climate Sensitivity is not a random variable; it is effectively a constant; so it does not have a variance. The variance of estimates of Climate Sensitivity arises from natural variance in the climate system, poor model fit and measurement errors.

The larger these sources of uncertainty, the higher the probabilities that will be attributed to extreme values of Climate Sensitivity because if the observed relationships are very uncertain they cannot rule out extreme values (values far greater than the best estimate of the sensitivity indicated by each study). But they do not provide any positive evidence that Climate Sensitivity actually has an extreme value.

Nonetheless, this has the paradoxical effect that the less well climate models fit the facts and the less well the facts validate 'the science' they incorporate, the greater the probability that will be attributed to extreme climate sensitivity. Common sense suggests this is not a solid basis for spending £trillions on mitigation policies so much as investing more effort in bringing models and theory into line with the facts.

Weitzman takes the simple average of all the PDFs listed by the IPCC which gives a 5% probability of the Climate Sensitivity exceeding 7°C is and a 1% probability that it could exceed 10°C. However, this exaggerates the risk of extreme Sensitivity. As Nordhaus points out, rather than simply taking the arithemtic average, its is more appropriate to treat these studies as independent samples of the 'true' distribution in which case they combine to suggest that there is only a 5% chance of the true value exceeding 4.6°C, not 7°C.[115]

The PDFs are usually constructed using Bayesian logic, a method of using empirical data to improve on our a priori estimate of the probability of different values of Climate Sensitivity.[116] It involves three steps.

• First, prior to observing the experimental data, the researchers set out their best estimates of the relative probabilities of different values of Climate Sensitivity in light of their existing knowledge or ignorance. This is called the 'prior' probability distribution.

115 *An Analysis of the Dismal Theorem*, William Nordhaus, 16 January 2009

116 More sophisticated explanations of Bayesian/inverse reasoning are available, e.g. *The Probabilistic Approach to Inverse Problems* by Klaus Mosegaard and Albert Tarantola, November 2002.

• Then, from the observations they calculate for each possible value of Climate Sensitivity – if that value were the true value - the likelihood of it giving rise to the observed data. (For most studies cited by the IPCC, the value of Climate Sensitivity which best fits the data is of the order of 3°C.[117] From the distribution of observations about the best fitting value it is possible to calculate the likelihood that, if the true sensitivity were, for example, 10°C, random fluctuations might nonetheless have made the observations support a best fit value of 3°C.)

• Finally, they weight the prior estimates of probability of each value of Climate Sensitivity by the corresponding conditional likelihood. This gives the 'posterior' estimate of probability, which will logically be an improvement on the 'prior' estimate.

However, the 'posterior' probability distribution will be influenced by the initial 'prior' distribution. The use of priors which attribute a uniform probability to all values in a given range, is common. They are sometimes described as 'non-informative', 'ignorant' or 'unbiased' But such a prior distribution is not unbiased (at least in most of the cases it is used for estimating Climate Sensitivity). All IPCC studies were stated to use[118] such a uniform prior – most standardised over the range 0°C to 10°C, others over an even wider range. That is to say, they start with the assumption that all values of Climate Sensitivity between 0°C and 10°C (or in some cases up to 20°C) are equally probable. As James Annan pointed out as an expert contributor in the IPCC process, the assumption that all values between 0 and 20°C are equally likely represents a prior belief that Climate Sensitivity is 70% likely to exceed 6°C and has a mean value of 10°C! Even when the range is truncated to 0°C-10°C this represents a prior belief that there is a 40% probability that Climate Sensitivity exceeds 6°C, and that it is twice as likely to lie outside the IPCC's 1.5-4.5°C range as inside it. That clearly does not reflect what people actually knew or believed to be most plausible prior to their subsequent observations.

A recent study[119] has shown that:

> "results based on a uniform prior distributions are sensitive to the selection of the upper bound … [and] the uniform priors that have been used represent extremely pessimistic beliefs about climate sensitivity that cannot truly be considered to represent either 'ignorance' or plausible prior beliefs of reasonable scientists."

On the other hand, using even a pessimistic version of expert prior opinion,

117 Recently, the Forest et al 2006 study - the only one comparing model simulations directly with a wide range of empirical data - has been called into question. It appears that rerunning the study using what appears to be the correct data set results in Climate Sensitivity closely constrained at 1°C instead of 3°C. *Questioning the Forest et al (2006) sensitivity study* Nicholas Lewis, 25 June 2012

118 The key study by Forester & Gregory, which was the only one involving instrumental evidence independent of climate models, did not use a uniform prior but was restated on that basis by the IPCC. *The IPCC's alteration of Forester & Gregory* Nicholas Lewis, 5 July 2012.

119 On the generation and interpretation of probabilistic estimates of climate sensitivity by Annan and Hargreaves. Frontier Research Centre for Global Change, Japan Agency for Marine-Earth Science and Technology May 2009.

when modified by observations from most recent studies:

> "the long fat tail that is characteristic of all recent estimates of Climate Sensitivity simply disappears, with a 95% limit for Climate Sensitivity easily shown to lie close to 4°C".

So Weitzman is using a set of studies that give unrealistically high probabilities of extreme values for Climate Sensitivity because they reflect unrealistic prior assumptions, not empirical observations or expert opinion. When reasonable assumptions are used instead, the significant probabilities he attributes to double-digit temperature increases largely evaporate. Moreover, although the prior distribution of some studies is truncated at 10°C, Weitzman assumes that for his average of all 22 studies there is no upper limit to Climate Sensitivity. It is this assumption which effectively abandons the notion that Climate Sensitivity can be derived from known physical laws.

Even though the high probability of extreme values of Climate Sensitivity may be largely a statistical artefact, this does not entirely invalidate Weitzman's Dismal Theorem. His presentation of his Theorem rested heavily on them. But its mathematical logic does not. It depends on the mathematical properties of the function he assumes describes the variance in our estimates of Climate Sensitivity (and the damage it may cause) and therefore of the subjective probabilities he attaches to values of Climate Sensitivity. The Dismal Theorem rests on the assumption that it will have a fat tail with no upper limit and that losses from high temperatures will reduce consumption exponentially. It follows that there is bound to be a finite risk - even if only one chance in a million - of Climate Sensitivity being high enough to destroy humanity. So we should be prepared to pay virtually anything to avoid that risk.[120]

On the other hand, Weitzman's conclusion no longer stands if even a very high upper bound, beyond anything scientifically plausible enough to be used in climate models, is placed on the possible temperature change, or if the upper tail of the probability distribution is assumed to decline at a more credible rate.[121] One of the studies[122] used by Weitzman concludes that:

> "Climate Sensitivity of much greater than 6°C is hard to reconcile with the paleo-climate record, and that of greater than 8°C seems virtually impossible."

Indeed, as Lindzen noted above, if the value of Climate Sensitivity is very high the climate would have been so unstable that over the last few billion years life would have been extinguished.

120 See *On welfare frameworks and catastrophic welfare risks* by Antony Millner for a comprehensive survey of critiques of the Dismal Theorem. He concludes that the utility function Weitzman used to put a social value on catastrophes is particularly vulnerable to criticism. More recently, in *Cheering up the Dismal Theorem* Ross McKitrick points out another weakness in its utility function - namely the use of an approximate measure of change in consumption, which, when replaced by a more exact measure, removes the infinite valuation Weitzman puts on large damages.

121 *Bounded uncertainty and climate change economics* by Costello, Neubert, Polasky and Solow, PNAS May 2010.

122 Annan et al

In the initial version of his Dismal Theorem, Weitzman implied that the existence of a 'fat-tail' of probabilities that Climate Sensitivity has a high value is mathematically inevitable. He accepted that the natural variance giving rise to the uncertainty in observed values of Climate Sensitivity may well be 'normally' distributed - the most common distribution in nature which means probabilities of high values decline exponentially and are therefore 'thin-tailed'. However, we do not know the true variance of that normal distribution so must use an estimate of that variance, the resultant estimated distribution of probabilities will be described by a Student-T distribution which is 'fat-tailed'.[123]

More recently[124], Weitzman has implicitly acknowledged that since the posterior PDF reflects the prior, whether it is thin-tailed or fat-tailed ultimately reflects the researcher's judgement – though he argues for the latter. This makes the applicability of his Dismal Theory itself a matter of judgment.

If we judge that the paleo-record suggests climate sensitivity has not had an extreme value, plausible science suggests likewise, and observations are only compatible with high sensitivity if other factors which should soon disappear have concealed this – there is no reason to apply the Dismal Theorem, at least until we know more.

To summarise: Weitzman has raised serious questions about the applicability of conventional cost benefit analysis in situations of uncertain risk to the future of the human race. But he has failed to demonstrate that this applies to the problem of man-made global warming even if, as is inherent in his thesis, we jettison claims that the science is known, certain and based on physics. We would have to accept:

- that statistical analysis of badly-fitting climate models can tell us that the climate sensitivity to greenhouse gases goes way beyond what science has postulated or has yet been observed (but which, if true, will rapidly become evident, giving us time to accelerate mitigation efforts);

- that even though the worst impacts of high temperatures would take centuries to take effect, we could neither reverse nor adapt to them;

- that civilised humanity would succumb to rapid temperature increases which primitive humanity survived;

- that we should ignore potentially graver risks to humanity arising from any crash programme to curb CO2 emissions;

- and that we should not by the same statistical logic devote all the world's

123 He also cites Roe and Baker's *Why is Climate Sensitivity so Unpredictable?* Science 26th October 2007, which shows that if uncertainties in feedbacks are normally distributed, those in Climate Sensitivity will be fat-tailed and skewed to extreme values. Roe and Baker acknowledge that their formula which "shows how uncertainties in feedback lead to [enhanced] uncertainty in a system of linear feedbacks... can be shown to be algebraically equivalent to a Bayesian derivation of a "posterior" distribution based on a uniform previous distribution of feedbacks".

124 Martin Weitzman *On Modelling and Interpreting the Economics of Catastrophic Climate Change* Review of Economics and Statistics 2009

available resources to preventing other low probability threats which really would exterminate humankind.

CHAPTER 7 – IMPLICATIONS OF STERN REVIEW FOR DEVELOPING COUNTRIES

The Stern Review largely justifies its call for drastic restraint on carbon emissions by invoking developing countries as the principal victims of global warming. In fact, they could be the main victims of over ambitious attempts to prevent global warming.

Stern is right that poor countries, despite having contributed least to the increase in greenhouse gases, are the most vulnerable to changes in the climate (whatever its cause). But they are more vulnerable precisely because they are less developed. The most devastating natural disasters – be they caused by weather, earthquakes or disease – occur in poor countries, not because of their geography or climate, but because they are more vulnerable to the vagaries of nature. Economic development – the accumulation of capital incorporating modern technology – equips countries to avert, resist, prepare for and respond to natural disasters. In developed countries, most people live in solid buildings with foundations; they can afford to build flood barriers (even if, as in New Orleans, they sometimes neglect to maintain them); they have been able to eliminate diseases like malaria; they have roads and communication systems that enable rapid response to any threat; their agriculture is diversified and able to respond to changing circumstances.

The Review's estimates of future damages make no allowance for the fact that as they develop, poor countries will become less vulnerable to climate change. The model it uses recognises that rich countries are less vulnerable to climate change than poor countries. But it assumes that less developed countries will retain their current degree of vulnerability even when they attain, as they are projected to do, the level of income that developed nations enjoy today.

The Stern Review highlights some very alarming sounding claims about the likely impact of global warming on the poorest countries.

> "By 2100, in South Asia and sub-Saharan Africa, up to 145 - 220 million additional people could fall below the $2-a-day poverty line, and every year an additional 65,000 - 250,000 children could die compared with a world without climate change."[125]

This creates the impression that in 2100, if we do not prevent climate change, there will be hundreds of millions more poor people and hundreds of thousands more child deaths than at present. In fact, there will be far fewer of either, even on the most extreme scenario. The figures in the (non-peer reviewed) study[126], which Stern cites as his source, indicate that if there is no

125 Stern Review Impacts of Climate Change on Growth and Development p 63

126 Edward Anderson, *Potential impacts of climate change on $2-a-day poverty and child mortality in Sub-Saharan*

climate change the number of child deaths will fall by 56%, as against 53% if climate change is at the most extreme end of the IPCC projections (the 95% decile of the High Climate version of the scenario assuming the most rapid increase in population and lowest growth of incomes). Although Stern appears to be quoting ranges within which projections are likely to fall, he is actually quoting the top end of the two most extreme scenarios cited in the study. The lower end of the range of projections actually shown in the study is for virtually no impact of climate change on either poverty or child mortality. Moreover, the projections in the study simply assume a mechanical relationship persists between child mortality and GDP. As the study itself acknowledges, it

> "assumes no further reductions in poverty or child mortality from net improvements in income distribution within countries, or from 'exogenous' sources of child mortality reductions such as global vaccination programmes. These may be significant in practice, but are difficult to project. Including them would tend to reduce the estimated impacts of climate change on poverty and child mortality in absolute terms."

More important than this egregious alarmism are the Review's policy prescriptions, which would inhibit the capacity of poor countries to develop economically. Economic development as we know it involves harnessing energy to replace or supplement human brawn. The cheapest source of energy is hydrocarbons.

In the absence of any agreement to limit emissions, the bulk of future growth in emissions – and of the totality of emissions – is expected to come from the developing world.

To the extent that poor countries are prevented from harnessing hydrocarbons to develop their industries and well-being they will not only remain poor, they will also remain more vulnerable to the impact of climate change. And climate change will continue to occur even if humankind stops emitting greenhouse gases entirely.

The Review is somewhat coy about how much it expects developing countries to restrict their CO2 emissions to meet its global emissions target. It cites a study by *Hohne et al.*[127] of how much each region would be permitted to emit, under several alternative strategies, to meet the aim of preventing global emissions exceeding 550 ppm of CO2 equivalent. This shows Africa being held back to between a quarter and a half of the growth of emissions to be expected under 'Business as Usual', and East Asia to less than a quarter of its 'Business as Usual' needs. South Asia is, for some reason, allowed slightly more leeway on some strategies so that it can emit between a quarter and three-quarters of its 'Business as Usual' needs.

Africa and South Asia Overseas Development Institute 2006

127 Stern Review Box 22.2 based on *Options for the second commitment period of the Kyoto Protocol* by Hohne, Phylipsen, Ullrich and Blok (2006)

To allow developing countries even this severely restricted growth of emissions, all developed countries will have to reduce their emissions by between 75 and 85% of current (e.g. 2006) emissions by 2050.

Elsewhere in the Review, Stern admits that cuts on this scale are unlikely to be possible:

> "…. great uncertainty remains as to the costs of very deep reductions. Digging down to emissions reductions of 60-80% or more relative to baseline will require progress in reducing emissions from industrial processes, aviation, and a number of areas where it is presently hard to envisage cost-effective approaches".[128]

So Stern, along with similar studies by the EU, envisages developed countries reaching their targets by buying 'emission permits' from developing countries. In other words, rich countries will reduce their emissions by less than the unrealistic 60-80% range in return for paying poor countries to restrict their emissions even more severely than the study by *Hohne et al.* quoted above. An EU study published shortly before the Review and using a similar methodology concluded that:

> "Widespread international participation in lowering the cost of emission reductions is shown to be crucial. … the costs could rise by a factor of three or more without the use of the flexible mechanisms of the Kyoto Protocol [i.e. emissions trading]."[129]

Indeed, the working paper for this study showed that the cost to the EU of cutting emissions by 20% by 2025 would be reduced from 1.67% of GDP to practically zero as a result of allowing the EU to buy credits under the Clean Development Mechanism and Joint Implementation schemes.

By definition, that involves paying developing countries to use more costly technology than they would otherwise have done or to forego development of their energy needs.[130] It is simply not credible that poor countries can develop as fast as they otherwise would, even with Emission Trading revenues, if they are constrained to use high-cost or low-energy routes. Subsidies for low carbon development will divert aid from other uses, burdening developing countries with an additional layer of bureaucracy and creating huge opportunities for abuse. Countries will have an incentive to propose carbon-intensive projects unless they are paid not to pursue them. That is precisely what has been happening under existing Kyoto mechanisms for trading carbon entitlements.

In short, all alternative sources of energy are extremely expensive relative to fossil fuels and often depend on conventional power stations as back-up. Humankind has come to rely on fossil energy because it is relatively cheap

128 Stern Review p 276 printed version.

129 Communication From The Commission To The Council, The European Parliament, The European Economic And Social Committee And The Committee Of The Regions: *Winning the Battle Against Global Climate Change* {SEC(2005) 180} p15

130 The one exception is payments to prevent deforestation, which is a major source of emissions.

and convenient; our whole prosperity and way of life is dependent on abundant energy. Ordinary people in developed countries are materially well-off largely because they use lots of energy. People in poor countries are poor because they do not yet have access to affordable energy. The process of leaving their poverty behind involves constructing power stations and electricity grids, swapping wood and biomass-burning stoves (which kill nearly 2 million poor people annually[131]) to cook and heat with coal, oil, gas or electricity; acquiring vehicles to travel beyond their villages and take their goods to market.

Armchair environmentalists may romantically imagine us returning to the simple life without dependence on fossil fuels which they imagine poor people enjoy. In fact, it means lives of grinding toil – where water is hauled every day rather than pumped through pipes; where fields are tilled and crops harvested by hand rather than with tractors and combine harvesters; where surplus crops – if any surplus can be produced without fertilisers - must be carried to market on your own or your animal's back; where you have no light to read or study by in the evening; where you cannot run any of the domestic appliances, from fridge to TV, which we all take for granted; where you cannot buy cheap clothes, food, and mass-produced goods made elsewhere because there is no transport to bring it to local markets; where hospitals cannot run X-ray machines, sterilise equipment or keep drugs cool because they have no electricity.

Even if that is an attractive vision to some Western intellectuals, it is perfectly clear that every developing country in the world wants to acquire as rapidly as possible what we in the developed world take for granted. To do so they need abundant energy as economically as possible; they are not going to invest their limited capital in new low-carbon technologies which will give them only a fraction of the power they could have from conventional sources.

Stern's approach would require them to do so. It would put the interests of a future rich world ahead of those of today's poor.

However, fortunately for today's poor, the governments of the developing world are unlikely to heed Stern's injunctions to restrict their carbon emissions. They may pay lip service to concerns about global warming insofar as is necessary to milk the carbon credits schemes. But they will go ahead and industrialise, generating more energy, consuming more fossil fuels and becoming the dominant contributors to rising emission levels whose growth will not be markedly slowed by the self-imposed austerity of the EU, however extreme.

Lord Stern promotes the delusion that developing countries may be willing to put curbing emissions ahead of growth:

"Some countries are already engaged in policies that would make it

131 www.cleancookstoves.org

> easier to move in these directions [full emissions trading ...or carbon pricing]; for example, China's programme to reduce energy use by its 1000 largest companies."

Western intellectuals have long had a propensity to view distant, autocratic regimes, particularly China, through the rosiest – or in this case, greenest – spectacles. However, China is simply trying to ensure it gets as much growth as possible from every unit of energy it uses. Prior to 2000, its energy consumption grew about 8% for every 10% rise in GDP. For some reason, this pattern deteriorated in the early years of this century and China found energy use rising more or less in line with GDP. The target in its national plan was to get back to the previous relationship – an 8% growth in energy for every 10% rise in GDP. Stern says this "implies a reduction (sic) of approximately 170 Mtoe". In fact, far from a reduction, it means that instead of rising by five times this amount, China's energy requirement would rise by 'only' four times. Since the Chinese intend to grow their economy very rapidly, their emissions will continue to far outstrip those of any western nation. They will make some use of wind, hydro and nuclear power – and being a vast nation the absolute number of windmills etc will be large and much is made of this. However, these will supply only a small proportion of China's energy needs, the overwhelming bulk of which will come from fossil fuels.

CHAPTER 8 – POLICY IMPLICATIONS

When told his theories contradicted the facts, Hegel replied: "So much the worse for the facts!"

Stern's policy conclusions

Stern concludes that the world must agree to prevent cumulative emissions in the atmosphere exceeding 500 to 550 ppm of carbon dioxide-equivalent. The upper limit of this range is roughly double the level of about 280 ppm immediately prior to the industrial revolution. The current level is equivalent to 430 ppm of CO2-equivalent and is rising by 2-3 ppm annually.

Current emissions worldwide are equivalent to over 42 gigatons of CO2-equivalent a year. Stern puts the maximum amount which can be absorbed by the oceans and biosphere at some 5 billion tons. So stabilisation – whatever the target level - will require ultimately reducing emissions to that level. That is more than 80% below current emissions and an even greater reduction relative to the level they would reach in the absence of efforts to reduce emissions.

Stern calculates that the path towards stabilisation will require "deep emission cuts of at least 25% [below current world levels] by 2050". Given that by then the world economy is expected to be some three to four times larger than today, emissions per unit of GDP would need to be cut by three quarters. However, to allow the developing world some leeway for the massive expansion of energy usage needed to raise living standards, developed countries must bear the bulk of the cuts, reducing their emissions by 60-80% by 2050 and decarbonise almost completely after that.

This will require imposing a tax (or equivalent via emission permits) starting at $312 per ton of carbon emitted[132], reflecting the social cost of carbon. Using Stern's assumptions, Nordhaus[133] estimates this would need to rise to $950 by the end of this century. This is far higher than most estimates of the social cost of carbon. A study by Tol[134], mentioned in the Review, found that estimates of the social cost of carbon from 28 published studies had a huge range. However, the mode was just $2 per ton of carbon, the median $14, the mean $93 and the 95th percentile $350.

The costs of decarbonising start now but the benefits of less global warming will come centuries hence. Stern concludes that, on his optimistic assumptions about the cost of almost completely decarbonising the

132 Stern Review Chapter 13.2 p 322.

133 Nordhaus *A Question of Balance* 2008 p 92.

134 Tol *The marginal damage costs of carbon dioxide emissions: an assessment of the uncertainties,* Energy Policy 33 2005.

economy, the aggregate cost can be limited to 1% of GDP - though in the main text it is shown as in the range -1% to 3.5%. More recently he has doubled his central estimate of the cost to around 2% of GDP on the presumption that we aim for the lower end of his target range of 500 to 550 ppm of CO2-equivalent.

On his base line scenario, Stern does not expect the total impact of global warming on GDP if we do nothing to exceed 1% of GDP until the end of this century. And even on the most pessimistic scenario, for which he shows figures, he expects the loss of wellbeing as a percentage of GDP per head to average less than 1% over this century.[135]

He is demanding the world accepts costs of 2% of GDP, which will be over twice the total benefits over the whole of this century, in order to ensure that people in subsequent centuries are even better off than they would otherwise be.

The Consensus View

Stern's conclusions differ dramatically from those of most environmental economists who have carried out similar analyses using similar models also based on the IPCC scientific assessment. All agree that it is sensible to start now. But the consensus view is that the optimum path would be to start plucking the low-hanging fruit – emission reductions that cost little – and gradually ratchet up to undertake progressively more costly measures over time. This contrasts with Stern's call for urgent and drastic cuts.

The doyen of environmental economists is William Nordhaus, Sterling Professor of Economics at Yale, who has been evaluating climate policies for several decades. He concludes that:

> "... the best approach is one that gradually introduces restraints on carbon emissions… slow, steady, universal, predictable and boring - those are probably the secrets for successful policies to combat global warming."[136]

Another leading environmental economist, Professor Richard Tol of Sussex University, concludes that:

> "Estimates of the impacts of climate change do not support the current the-end-of-the-world-is-nigh hysteria … Current EU price for carbon maybe about right or too high."[137]

Likewise, Robert Mendelsohn, Professor of Economics at Yale, argues that:

135 Stern Review Figure 6.5 a & c.

136 Nordhaus *A Question of Balance* p 204.

137 Tol *The Impact of Climate Change and its Policy Implications*.

"The assumptions required to argue for aggressive near term abatement are long and unlikely. The prudent path is to begin with a modest abatement program that turns global as quickly as possible. The program should at first focus on being efficient and global in coverage. As time progresses, the targets of the program should be gradually tightened so that there is significant abatement planned for the second half of this century."[138]

Why do their prescriptions differ so widely from those of Stern?

Rather surprisingly, Stern does not even try to calculate an 'optimum path or target'. Indeed, he does not even purport to carry out a full cost benefit analysis of a range of options. Instead he plucks the 550 ppm target out of the air (not quite, since it coincidentally happened to be the target to which the British government had committed itself in 2003).[139] Others have evaluated targets of 650 and 750 ppm. Without calculating costs and benefits of any higher targets, Stern simply asserts that they would be intolerable. He does refer to a lower target of 450 ppm but rejects it as unrealistic and probably three times as costly as his chosen target. Selecting a target and comparing it with doing nothing is not proof that the target is optimal.

Stern rightly bases his analysis on the familiar economic concept that global warming is an 'external cost'. Those who emit greenhouse gases do not bear the costs they impose on others. As a result, they have insufficient incentive to curb their emissions. The normal solution is to 'make the polluter pay' by imposing a tax equal to the external cost - often referred to as the 'social cost of carbon'. The social cost of carbon would be expected to rise over time to reflect the fact that extra damage imposed by additional carbon emissions rises progressively as the atmospheric concentration rises. Most economic studies therefore focus on calculating the level and future trajectory of the social cost of carbon necessary to optimise the balance between costs and benefits. Yet Stern gives only a fairly cursory mention of the social cost of carbon, perhaps because he does not want to dwell on how high it would need to be from the start to achieve his drastic cuts in emissions. In his brief discussion of the social cost of carbon, Stern suggests that his analysis "points to a number around" $85 per ton of CO2 ($312 per ton of carbon). By contrast, a study by Tol of 103 estimates drawn from 28 published studies showed that the mean value was $93 per ton of carbon.

The rationale for a gradual ratcheting up, rather than a crash programme, is fairly obvious:

• Some ways of reducing carbon intensity are simple and low-cost: we should focus on them before spending our scarce resources on more expensive projects to reduce climate change.

138 Mendelsohn. *Yale Symposium on the Stern Review* 2007

139 Cmn 5761 Energy White Paper Our Energy Future - creating a low carbon economy Feb 2003.

• It is less costly to introduce low-carbon technology as and when existing capital needs replacement than to scrap and replace plant prematurely.

• It is more economic to invest in R&D and wait until competitive low-carbon alternatives have been developed than to invest in half-developed technologies,

• It is more beneficial for the poorest countries to invest in development, thereby simultaneously raising their living standards and reducing their vulnerability to climate change. Diverting investment away from development into high cost, low carbon, low energy projects will leave them both poor and vulnerable while only marginally reducing the scale of climate change.

• It is more economic to invest in adapting to modest climate change than to try to prevent it entirely or before new technologies become available. Moreover, adaptation does not require virtual unanimity internationally.

• Even in rich countries it may be more sensible to invest in general economic growth which will increase the resources available to future generations to tackle climate change rather than diverting it to projects which will only marginally reduce climate change.

• A gradual ramp up will allow time to learn from observation and experience about climate sensitivity, the impact of global warming and how best to cut emissions. If Climate Sensitivity is as high as some fear, that should rapidly become evident (see Annex to Chapter 6) – if not, we have more time to tackle the problem. This should reduce some of the huge uncertainties affecting our current projections of climate change. The PAGE2002 model used by Stern shows that if in a decade we get information halving the range of values for climate sensitivity that is worth $300-400 billion.[140]

• It becomes increasingly likely with the passage of time that the world will develop low cost, harmless methods of absorbing, masking or reducing carbon emissions.

Climate models have a role to play in this issue but there are risks in using complex models, not just that used by Stern, namely that they can both override commonsense and conceal from the model user the extent to which this has happened.

Thus, readers of the Stern Review are left entirely unaware that Stern's plan would mean that the costs of cutting emissions would exceed the benefits from reduced global warming for almost all of this century. This is before making any allowance for the tendency of the Review to exaggerate the likely damage from rising emissions and to understate the costs of reducing them rapidly. The only justification for his call for a hugely costly crash

140 Yale Symposium on the Stern Review: PAGE modelling system. Chris Hope. 2007

programme to cut emissions is because his methodology counts potential savings several centuries ahead as being almost as important as costs incurred this century. Moreover, his model ignores the opportunity cost of diverting investment away from alternative, more productive, investments. It also ignores the fact that economic growth would reduce the vulnerability of poor nations to climate change. On the other hand, it builds in the assumption that however technologically advanced the world becomes, and however long the world continues, humankind will never develop ways of abating, undoing or adapting to global warming.

Up to now, British policy on climate change has been driven by competition between political parties to prove their virtue. All main parties have also been in thrall to the myth – presumably a hangover from our liberal imperialist past - that Britain only has to 'show leadership' and the rest of the world will respond. Nordhaus derides the whole British approach as "the world according to Government House utilitarianism". Our political parties have measured their virtue by the austerity of the targets they sign up to, rather than the benefits their citizens' sacrifices will bring, adopted a hodge-podge of individually fashionable policies regardless of cost or coherence, and - rather than pursuing evidence-based policy – they have relied on 'policy based evidence' like the Stern Review.

The most marked symptom of this pursuit of virtue rather than effectiveness has been an almost heroic disregard of costs. It should not need saying – if the costs of a proposed strategy exceed the benefits one should amend the strategy or seek another. Unfortunately it does need saying.

The government is required to publish an Impact Assessment of the costs and benefits of any legislation it introduces. The purpose of this requirement is to enable Parliament to "determine whether the benefits justify the costs".[141] The Government duly produced an Impact Assessment[142] of the Climate Change Bill as it passed through Parliament, showing that the potential costs - £205 billion - were almost twice the maximum benefits of £110 billion. Moreover, these cost estimates excluded transitional costs which were put at about 1% of GDP until 2020, omitted the cost of driving carbon intensive UK industries abroad, which was said to be significantly likely, and assumed that businesses would identify and implement optimum new carbon-efficient technologies the instant they become available. Nonetheless, Ministers ignored their own figures, refused to discuss them and proceeded to drive the Bill through. This must be the first time any government has recommended Parliament to vote for a Bill that its own Impact Assessment showed could cost far more than the maximum benefits.

The costings of the Bill were based on the original legally-binding target of cutting emissions by 60% by 2050. During the passage of the Bill, an amendment proposing an even more onerous target of 80% was supported by the opposition parties. To avoid being outbid in the 'austerity equals

141 Impact Assessment Guidance - BERR

142 DEFRA Climate Change Bill Impact Assessment 1st June 2008

virtue' stakes, this was accepted by the government. The government then had to produce a revised Impact Assessment incorporating this new target. Normal economic laws suggest that a more onerous target would mean rising marginal costs and falling marginal benefits. So the disparity between costs and benefits was expected to widen. The new Impact Assessment did indeed nearly double the estimate of potential costs – to £404 billion, still excluding transitional costs now put at between 1.3% and 2% of GDP up to 2020 etc. However, the government, stung by criticism (albeit by a single MP) that its previous Impact Assessment showed costs exceeding maximum benefits, increased its estimate of maximum benefits no less than tenfold to over £1 trillion. As so often in the debate on Global Warming – when the facts do not fit the theory, the facts get changed. If nothing else, the ability to conjure up a tenfold increase in benefits illustrates how flaky are the figures on which climate policy is based and how policy drives evidence rather than follows it.

The cost of unilateralism

Even so, to justify this revised figure the government had to make the explicit assumption that the rest of the world will impose similar targets on themselves (which no other country has yet done). The revised Impact Assessment takes into account that the benefits of Britain making a given cut in emissions – be it 60% or 80% - depends on whether the rest of the world does likewise. This is because the damage done by an extra ton of carbon dioxide is greater the higher the concentration of carbon dioxide in the atmosphere. The first Impact Assessment effectively assumed that other countries would cut their emissions regardless of whether we did so, so the 'social cost of carbon' used to value our emission cut was low. The revised version compares the cost of our emissions if neither the UK nor the rest of the world cut their emissions – in which case the social cost of carbon is high – with the cost of emissions if we all cut them - in which case the damage is low. So the estimated benefits from the UK cut are larger. As the then Climate Secretary, Ed Miliband, explained:

> "The benefits of acting to reduce emissions are that future damages from climate change are avoided. These benefits are much greater if the world acts together than if the UK acts alone."[143]

This does call into question Parliament's decision to bind governments by law to pursue these targets regardless of whether the rest of the world follows our example. Indeed, the Impact Assessment was quite explicit:

> "Where the UK acts alone, though there would be a net benefit for the world as a whole the UK would bear all the cost of the action and would not experience any benefit from reciprocal reductions elsewhere. *The economic case for the UK continuing to act alone where global action*

143 Letter from the Secretary of State for Climate Change to Peter Lilley 23rd April 2009.

cannot be achieved would be weak."(emphasis added)

The UK's contribution to world emissions is tiny – barely 2% of the total and less than the increase in China's emissions in a single year. Even if the EU as a whole were to act unilaterally, the reduction in global warming as a result of our sacrifice would be far smaller than if the rest of the world did likewise.

Stern is unrealistically optimistic in assuming that public opinion will force governments to sign up to and comply with a global agreement. He writes:

> "On many dimensions of international relations, governments make and respect international obligations because they are in line with perceptions of responsible and collaborative behaviour, and because domestic public opinion supports both the objectives and mechanisms for achieving them".

This is a fantasy view of the world. Many governments are not responsive to public opinion; in developing countries neither public opinion nor government policy have been persuaded to put mitigation of global warming ahead of development; and in countries which are taking action, public opinion was bound to become less enthusiastic as the costs are felt. Japan has stated that it will not renew its Kyoto obligations and Canada has resiled from the Kyoto Accords since Stern published his Review.

Unilateral action also puts British industry at risk. The government's Impact Assessment indicated that:

> "Research by the IPCC found relatively high risks of asymmetric mitigation action resulting in the transfer of productive capital to countries without carbon policies, known as 'carbon leakage'."

Moreover, it is a peculiarly masochistic sacrifice in that it does not reduce total emissions but simply transfers the industry generating them to other parts of the world.

Stern's optimism about the likelihood of legally binding international commitments to reduce emissions has proved greatly misplaced. In reality, there never was any chance of China or India signing up to any agreement significantly restricting their freedom to industrialise using the most economical source of energy available to them. And without their agreement the US would not participate whichever party is in power.

In the development of UK climate policy so far, if evidence has conflicted with policy either it has been ignored or more satisfactory evidence has been conjured up to justify policy. Rather than evidence based policy we have had policy based evidence. Sadly, the Stern Review was the most egregious exercise in 'policy based evidence'. It tried to demonstrate that the benefits of pursuing the government's targets would exceed the costs. To do so, Stern stretched the science of economics to the limits and beyond. In

his own unfortunate phrase, he had to deploy 'all the economics you ever learnt, and some more'. He had to ignore the established consensus of the economics profession and repudiate even the conclusions of the IPCC. But as I have tried to show: on any objective basis, he failed. The benefits of a crash programme to pursue the Stern Review's target do not exceed the costs. More credible strategies are available.

RECOMMENDATIONS

The Government should cease to rely on the flawed Stern Review to justify policy and should not base its climate change strategy on it.

The Government should commission a new Review:

a) undertaken by a balanced team reflecting a range of views on this subject,

b) with rigorous terms of reference and independent peer review,

c) tasked to assess and cost alternative strategies.

• Ideally such a Review would be undertaken under the auspices of an international body like the OECD if its objectivity can be ensured.

• The government should prescribe the same discount rate for assessing costs and benefits of climate policies as it uses for all long term public projects – and show the sensitivity to alternative plausible discount rates.

• The Review should also calculate the Internal Rate of Return of alternative pathways for tackling global warming.

• The Review should assess the impact specifically on the UK, as well as globally, of global warming and of strategies to mitigate it.

• The Review should take into account the extent to which UK policies drive carbon emitting industries overseas and include in figures for UK emissions estimates of carbon emitted to produce goods imported into the UK.

• The Review should assess the cost and benefits for scenarios involving varying degrees of international cooperation.

• Parliament should amend the Climate Change Act to remove the legal requirement on the UK to act unilaterally regardless of whether other countries follow our lead.

• Meanwhile, the government should pay heed to the Impact Assessments it produces for each element of climate change policy instead of ignoring or massaging them.

• Government should also review how much existing policies have actually reduced carbon emissions and at what cost per ton of emissions reduced.

• If the government retains a commitment to imposing the social cost of carbon via tax or emissions quotas, it should abandon specific targets or subsidies for individual renewables.

• In the absence of a new Review, government strategy should at most be based on:

a) gradually ramping up incentives to reduce carbon emissions,

b) cost effective measures to increase energy efficiency,

c) greater focus on incentivising Research and Development,

d) acceptance that developing countries need to develop the cheapest energy sources available to them,

e) more emphasis on adaptation to climate change as it occurs,

f) focussing development aid on helping vulnerable countries adapt to climate change, whatever its cause.

Author's Acknowledgements

I am grateful for the invaluable help and comments I have received from Professor Richard Tol, Andrew Tyrie MP, Lord Lawson, Tim Curtin, Rupert Darwall, Professor David Henderson, Nic Lewis, Jeremy Mayhew, Professor Sir Alan Peacock, Professor Ross McKitrick, Dr Matt Ridley and Lord Turnbull. The remaining errors and omissions are my responsibility.

The Global Warming Policy Foundation is an all-party and non-party think tank and a registered educational charity which, while open-minded on the contested science of global warming, is deeply concerned about the costs and other implications of many of the policies currently being advocated.

Our main focus is to analyse global warming policies and their economic and other implications. Our aim is to provide the most robust and reliable economic analysis and advice.

Above all we seek to inform the media, politicians and the public, in a newsworthy way, on the subject in general and on the misinformation to which they are all too frequently being subjected at the present time.

The key to the success of the GWPF is the trust and credibility that we have earned in the eyes of a growing number of policy makers, journalists and the interested public.

The GWPF is funded overwhelmingly by voluntary donations from a number of private individuals and charitable trusts. In order to make clear its complete independence, it does not accept gifts from either energy companies or anyone with a significant interest in an energy company.

Views expressed in the publications of the Global Warming Policy Foundation are those of these authors, not those of the GWPF, its Trustees, its Academic Advisory Council members or its Directors.

Published by the Global Warming Policy Foundation
ISBN: 978-0-9566875-9-3

For further information about the GWPF or a print copy of this report contact:

The Global Warming Policy Foundation
1 Carlton House Terrace, London SW1Y 5DB
T 020 7930 6856
M 07553 361717
www.thegwpf.org

Registered in England, no 6962749
Registered with the Charity Commission, no 1131448